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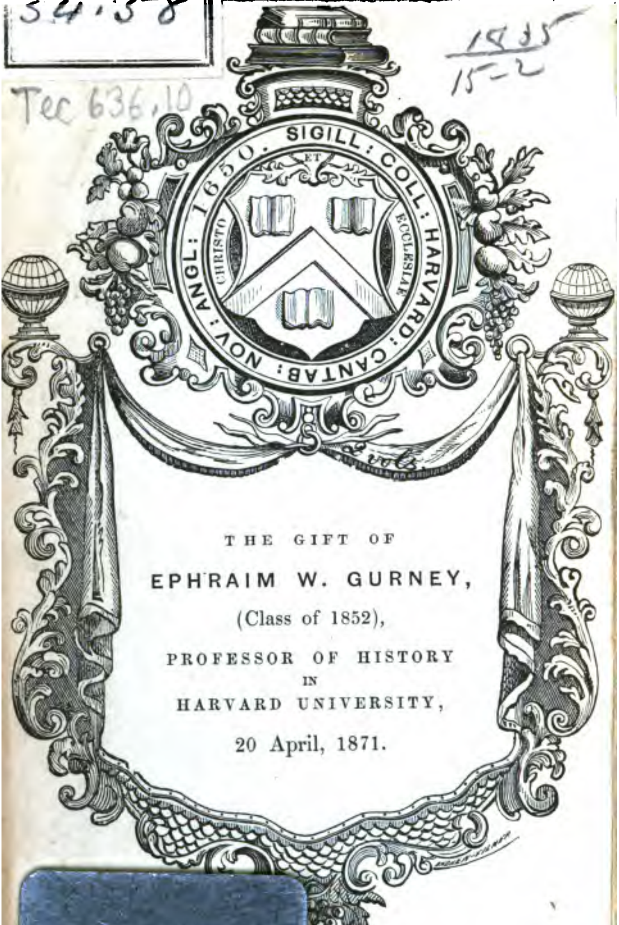

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**EPHRAIM W. GURNEY,**

(Class of 1852),

PROFESSOR OF HISTORY
IN
HARVARD UNIVERSITY,

20 April, 1871.

# BRITISH MANUFACTURES.

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# BRITISH MANUFACTURES

## SERIES IV.

### INTRODUCTION.

It is generally found, when an attempt is made to classify manufactures with any strictness, that the difficulty of deciding on the contents of each group becomes more and more felt as the classification advances. This arises from the circumstance that each complete occupation, or chain of processes, may be regarded in many points of view, giving rise to as many modes of grouping as there are phases of character.

Let us take the manufacture of a piece of floor-cloth as an example, and see in what various lights it may be regarded. In the first place, it might be grouped among those in which the arts of design are especially available; inasmuch as the pattern, which by various processes is painted on the cloth, constitutes one of the chief elements in the value of the product: in this point of view, the manufacture would be grouped with calico-printing, with the weaving arts generally, with paper-staining, and with others in which the draftsman precedes the mechanic. In the next place, it might be grouped among the *painting* arts, and occupy a medium position between painting as a "fine art," and the more mechanical occupation of house-painting. In the third place, it might be ranked among those arts in which a woven material of hemp or flax is employed, and this would give rise to a mode of grouping wholly different from both the others. Lastly, it might be deemed one of the arts contributory to the fitting and furnishing of a house; and would then be included among many which had no other bond of connexion. It would not be difficult, in like manner, to lay down other modes of grouping this branch of manufacture.

Without attempting, then, any very clearly marked kind of classification, we shall give in this volume a sketch of several interesting branches of manufacture which are so far connected as to fall within the last of the four modes of grouping just alluded to—namely, they will relate chiefly to the fittings or finishing of a house, or to some of the articles of furniture or of ornament therein deposited. The subject, if we chose so to make it, might include an almost unending variety of details; but for obvious reasons a selection only can be here given.

# CHAPTER I.

## MARBLE AND STONE WORK.

The cutting of a piece of stone, and bringing it to a form and appearance adapted to the purposes of the builder, are operations which, until the last few years, have undergone but a very slight amount of change. The pickaxe at the quarry, and the saw and chisel at the mason's yard, have probably for ages been the instruments by which these operations have been conducted; and, indeed, so far as regards the common building-stones, the same remark may be made in our own day. The more costly kind of stone, such as *marble*, which, from its nature, is susceptible of a high and durable polish, requires for its due preparation an amount of labour far exceeding that which is customarily bestowed upon the commoner kinds of stone; and this circumstance has led, within a period comparatively recent, to the construction of machines which enable the processes of sawing, grinding, polishing, &c. to be performed with more expedition and less expenditure of manual labour than characterized the same operations formerly.

So far as stone is employed in large blocks for the construction of buildings, strength and durability are the chief qualities for which the material is valued; but when we have a substance such as marble, in which delicacy and purity of colour are combined with a susceptibility of receiving a high polish, and of being cut into elegant forms, a new measure of value is obtained: *taste* and *beauty* are at once appealed to, and the refining influence which objects of taste exert on mankind is shared by this substance in common with many others. That this is felt to be the case, is shown by the evidence given before the Parliamentary Committee on the Arts and Principles of Design, in 1836. It appeared to be an opinion on the part of many members of the committee, that if so beautiful a substance as marble could be brought more plentifully and economically within the reach of the inhabitants of this country, it would tend to advance the arts of design, and to diffuse a taste for the elegancies which are so well appreciated in Italy. On this subject, Mr. Cowper gave the following evidence:—

"613. Would you not conceive, if the arts were generally diffused among the people, the black marble of Derbyshire and different marbles would be converted to purposes at present almost unknown?—Certainly.

"614. Is there not some tendency now existing towards the conversion of that and various marbles to purposes of art?—There is, both as to the various marbles and various other materials. At the marble-works, Esher-street, Horseferry Road, there is a beautiful system of machinery for working ornamental marble; mouldings, slabs, and pilasters of beautiful workmanship are executed in British and foreign marble at a low price. The whole is the contrivance of Mr. Tulloch, an independent gentleman of great taste, as his large collection of paintings by the old masters testifies. He, from observing the great use of marble in Italy and in other countries, contrived this machinery for the express purpose of introducing marble into more general use in this country."

After a few questions relating to a patent mode of carving busts in ivory, Mr. Cowper was asked—

"632. If applied to oak or hard wood, the expense would be considerably lessened ?—Yes; and I have seen the most elegant parquetry floor made by it, which would be too expensive to be attempted by hand. Much, if not all, of the Gothic oak carving for the new houses of parliament might be done by it; and with Mr. Tulloch's machinery in Esher-street almost all the Gothic stone mouldings might be executed; so that by this application of art to manufacture, the splendid palace of the legislature might itself be increased in splendour.

"633. Could it be used for working in wood and wainscoting, and for ornaments ?—Yes; and there would be no difficulty in doing so."

It is necessary to state the distinction between marble and other kinds of stone. This term is applied to those finer varieties of granular and compact limestone, which, being of a closer grain, are susceptible of a superior polish, and are remarkable either for their whiteness their blackness, or the beauty and variety of their colours. In former times the appellation of marble (derived from the Greek verb, to *shine* or *glitter*) was indiscriminately given to many stony masses that admit of being polished; and accordingly we find alabaster, serpentine, basalt, porphyry, &c. occasionally included under that term. At present, however, it is customary to confine the term "marble" to the kinds of limestone above alluded to, whether in a pure state, or varied with foreign substances mixed with or embedded in the mass, such as serpentine, hornblende, quartz, &c. Where a piece of marble is not purely white (and white specimens are very rare), it has received its tints generally from the oxides of iron, the solution of which has, wholly or partially, penetrated the mass previous to its complete induration. Blue and green marbles frequently owe their tints to minute particles of hornblende. The black varieties, such as those of Ireland and of Derbyshire, are coloured by carbon, and sometimes by a kind of bitumen.

The ancient statues, of which so many beautiful specimens are still remaining, were formed of marble obtained from quarries which are met with even in the present day; and the general character of all such quarries may be judged from a notice of those at Carrara. Several ridges of low hills near the town of Carrara have been known for the marble-quarries worked there ever since the time of the Romans. The quarries are more than a hundred in number, some furnishing the purest white marble which the sculptor can obtain, and others marble variously tinted and adapted for ornamental purposes. The quarries were worked throughout the flourishing period of the Roman empire; after which they fell into disuse, and did not resume their importance till the Pisans took possession of them in the twelfth century.

Of this assemblage of quarries Mr. Simonds observes— "Formerly on the sea-side, it now forms a deep nook in the mountain behind: but all Italy, all Europe, and all the world, might be covered with temples and peopled with statues of Carrara marble, yet the main stock would sustain scarcely a visible diminution by the loss of such fragments of its vastness. The rock is strewed over with these fragments detached from the heights by pygmies whom you scarcely see above, working with their puny tools, and blasting with gunpowder. The face of the noble rock, exposed for ages to the weather, is black; while the new fractures are dazzling white, and their crystal grain, dimly transparent, looks as if a single stroke of the chisel—a skilful one indeed—might make it breathe at once." * Twelve hundred workmen are constantly employed at the quarries; and the annual revenue is calculated at seven or eight hundred thousand francs. The blocks are carried down from the quarry in carts, drawn by oxen, to the Spiaggia, or beach of Avenza, where the storehouses are, and whence the marble is shipped on board the vessels that anchor in the roads. As the freight of the blocks would be uselessly increased if they were exported in misshapen masses, they are frequently sawn into squares by saw-mills, turned by some small streams which flow down the side of the hills in which the quarries are situated.

Captain Basil Hall, in his 'Patchwork,' speaks thus of the vast quarries at Syracuse in Sicily:—" Perhaps the most striking proofs of the magnitude of the old city of Syracuse are the enormous quarries from which the stone had been drawn in past ages to construct the houses and temples, the dwellings and places of amusement of the million inhabitants whom history tells us resided within the walls. One of these quarries, which is now the garden of the Capuchin convent, we examined minutely. It is a deep, wall-sided, irregular cut in the rock, said to be one hundred feet deep. At some places this large excavation is a hundred yards broad, at others

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* 'Tour in Italy and Sicily,' p. 576.

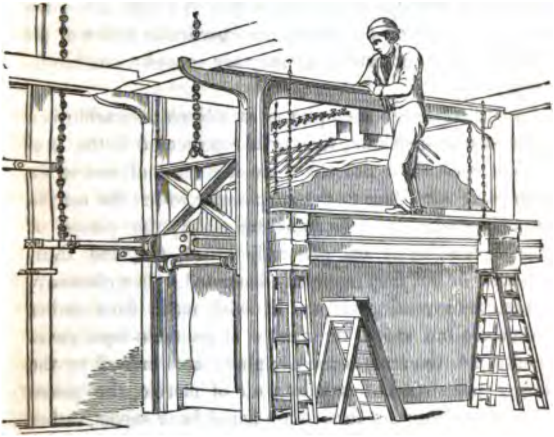
it is contracted to a tenth part of that width. The ground at the bottom is not level, but rises and falls, according, I imagine, as the piles of rubbish were moved hither and thither by the workmen. It is everywhere covered either with vegetables or flower-beds, either under the spade of the gardener, or thickly grown up with orange-trees, olives, limes, and figs, some of them absolutely like forest-trees; besides almonds, vines, pomegranates, and other trees and flowering shrubs, all luxuriating in the shelter of this singular excavation. The sides at most places are richly clad with a matting of ivy, it is difficult to tell how thick, which occasionally hangs down like a curtain, in front of enormous caverns receding far back into the living rock. . . . . In most of these quarries the marks of the workmen's tools are very apparent. It is even possible to tell the size and shape of many of the stones which have been cut out, and sometimes to follow the order in which they were removed. These trivial but distinct and indubitable traces of the handiwork of the ancients carry with them, it strikes me, a peculiar sort of authenticity and unpretending truth, which brings old times more vividly before our minds than the great works of art do. For it may be almost said that the statues and temples belong to a different and higher order of beings, with whom we moderns have little resemblance. When we lose ourselves in admiration of the Venus or the Apollo, or stand awe-struck before the Temple of Neptune at Pæstum, it is almost as difficult to bring the imagination up to the belief that we are of the same race with the men who executed these works, as it is when looking at the planet Jupiter, or at the ring of Saturn, to conceive that these stupendous bodies form an actual part of the same system to which we pygmies belong. We know by history in the one case, and by scientific demonstrations in the other, that it must be so; but it is difficult to take it all in. But the simple touch of a pickaxe on the face of the rock in an old quarry like that of Syracuse, tells quite a different story, and one which none can doubt. We almost hear the sound ring in our ears, and half wonder that we do not see the crowds of Greek or Roman workmen labouring round about us."

The process of quarrying presents various features, according to the nature and position of the stone or marble. At the Portland quarries, from whence such a large amount of building-stone is obtained, the arrangements are thus conducted:—The building-stone is in a horizontal layer, closed in above and below by strata of less valuable rocks. Above it is a thickness of more than thirty feet of such strata, all of which have to be removed before the Portland stone can be arrived at. There is first a certain thickness of surface soil to be dug away and removed. Then there are various layers of rock, which are separated into portable masses by wedges being driven into natural fissures. When one of these masses (which frequently weigh a hundred thousand pounds each) is loosened, it is very slowly moved from its place by jacks and levers, and hurled down into the sea as useless rubbish. Then comes the good Portland stone, which forms a layer about eight feet in thickness; and this layer has fissures in various directions, which enable the quarrymen to separate it into blocks of various sizes. In other cases, where the rock is more compact, the stone is cut or broken into separate masses by the chisel, by wedges inserted in grooves, or by blasting with gunpowder; and the masses so obtained are hewn into roughly squared blocks before leaving the quarry, in order to avoid the expense of transporting useless portions of the stone.

When blocks of marble or of stone are brought into the hands of the mason, they are by him wrought to various forms, fitted for different purposes in the building or decoration of an edifice. Within the last few years great progress has been made in the application of machines to the working of marble and stone; and there are now many establishments, especially one in Esher Street, Milbank, where great completeness of arrangement is shown in carrying out these operations. In such establishments there is usually a range or ranges of buildings, surrounding one or more open yards. The yards generally contain a store of large blocks of marble and stone; some in the rough state in which they were brought to London, either merely trimmed with the chisel or rudely sawn into thick slabs; others in a more or less prepared state. Blocks of black marble from Ireland, of the unusually large dimensions of thirteen feet by ten or eleven; blocks of white marble from Italy, much smaller in size, and exhibiting examples of the rude manner in which the hand-sawing of the Italians is effected, and blocks of various sorts of marble and stone —these are the rough working materials.

In the buildings surrounding the yard are usually placed the machinery for cutting the stone, all deriving their source of power from a steam-engine. Of these machines, one is a 'ripping-bed,' a machine for cutting slabs of marble into narrow strips or into small pieces.

Another is a 'grinding-bed,' on which the slabs are ground after sawing, and previous to the process of polishing. A third is a 'moulding-bed,' a machine by which pieces of marble are worked into the architectural form of mouldings, such as squares, fillets, beadings, hollows, and ovales. All these machines consist of various parts to which motion of some kind or other is given, in one of the many ways which are familiar to those accustomed to machinery, but which can scarcely be made intelligible to general readers by written description. Shafts, drums, bands, cog-wheels, racks and pinions, bevel-wheels—all are brought into requisition, according to the kind of motion and the circumstances under which it is to be produced. Another is a lathe of large dimensions, turned by a shaft connected with the other ma-



Machine for cutting blocks of marble.

chinery; at this lathe circular pieces of stone are moulded, or provided with the architectural mouldings just alluded to, and by it also circular columns are turned.

Various other machines are employed, the use of which may perhaps best be shown by tracing the progress of a block of marble through the several processes which it, or the pieces into which it is cut, undergo, till its final conversion into slabs, pillars, mouldings, plinths, vases, or other specimens of marble-work. We shall thus have an opportunity of describing the particular action of all the machines separately, as they are brought into requisition.

The first machine employed on a block of marble is a large sawing-machine, such as is represented in the preceding cut. The process of sawing must of course be regulated according to the purpose for which the marble is employed. In a monumental tablet, the pieces of marble employed are generally broad, flat, and thin, whether or not they be highly decorated. In a chimney-piece, the several parts are likewise made from rather thin slabs and strips; in marble steps, table-tops, pavements, &c. the same remark applies; and indeed in the larger proportion of articles made of marble, the pieces from which they are formed are flat slabs or sheets, rather than massive pieces. In many of the ornamental purposes to which marble is applied, a foundation of commoner stone, of brick, of wood, or of cement, is first formed, and then the marble is superposed merely as a sort of casing. It results from this mode of using it that a block of marble is in most cases converted into slabs of an inch or so in thickness before being applied to its ulterior purpose.

This first process of sawing is that in which the application of machinery is perhaps of the greatest importance, not only as regards the expenditure of manual labour, but also in reference to the accuracy with which the cutting is effected. With regard to the first point, many persons must have observed the singularly inefficient way in which the muscular power of a man is exerted in the common mode of sawing a stone. He sits at one end of the stone, grasping with his hands one end of a frame which contains an iron saw or cutter, and this saw he pushes to and fro as a means of dividing the block of stone or marble into slabs. Now it is manifest on a very little consideration that his muscular strength is not equally effective as a working power during these reciprocal movements; to push and to pull, to draw upwards and to draw downwards, to extend the hands from the body and to draw them to it, are respectively efforts which produce very unequal effects. If we watch the proceedings of a stone-sawyer, we shall also see that the saw frequently 'jars,' or has a tremulous motion consequent on the unequal manner in which it is moved; the result of which is, that the cut is not equally effective throughout the whole length of the block. All these circumstances combine to render the cutting by hand a very slow one.

With respect to the accuracy of the cutting, it may well be supposed that this is with difficulty attained by hand. The blade of the saw or cutting instrument is not above three or four inches wide, and is extremely apt to twist a little out of the vertical plane. If we were to attempt to cut through a large cheese with a common knife, the cut would be more and more irregular in proportion as the blade of the knife was narrower. So in the case of the stone; the narrowness of the blade—necessary to ensure its easy passage through the stone—renders it so liable to deviate from the vertical plane, that a perfectly level cut is almost unattainable by hand. This irregularity produces two ill consequences: it renders a laborious process of grinding necessary, in order to produce a level surface; and it occasions a waste of material, which is of serious importance if the quality of the marble be valuable. As an instance of this latter fact, we have seen two halves of a large and very fine block of statuary marble, which had been cut into two in Italy before exportation. The cutting had been effected by hand; and on glancing the eye along the surface of one of the pieces thus cut, it was obvious that the surface was about nine inches out of a true plane, the saw having twisted in various directions during the process of cutting. The distortion thus occasioned affected both halves equally, for a convex protuberance in one half had a corresponding depression on the other; and to bring both of these to a true surface, the middle portion of the one and the edges of the other had to be sawn or ground away to the depth of nine inches. It happened that this block was one of the finest specimens of purely white marble, a fact which could not be fully ascertained until the cut was made; the quality was so valuable, that the portion wasted by the irregular sawing would, if cut into slabs, have been worth a sum estimated by the proprietors at nearly a hundred and fifty pounds.

These are some of the circumstances which render the employment of machinery very important; and Sir George Wright and Sir James Jelf many years ago devised machines for these purposes. Their attempts, from various causes, were not permanently successful; but the mechanism of Mr. Tulloch has now been in operation several years. The sawing-frames each consist of a cast-iron framework, to hold the working machinery together, about twelve feet long. A horizontal rectangular frame, longer than the block to be cut, and wider than the block is thick, has mechanism at each end by which a number of saws may be fixed parallel to the length of the frame, and with the blade of each saw in a vertical plane. By means of pins and wedges, the saws can be fixed at any required distance apart; suppose, for instance, that a block is to be cut into a number of slabs each one inch thick; an equal number of saws would be fixed in the frame strictly parallel one to another, and exactly an inch apart: so that the saws themselves would ensure the accurate regulation of the thickness of the slabs. The saw-frame is capable of sliding in vertical grooves in the cast-iron supporters, and is balanced by weights connected with it by a chain passing over a pulley above; the saws are thus kept at a height from the ground corresponding to the part of the block which is being cut; and as they are a little heavier than the balance-weight, they gradually descend by their own pressure as the cutting proceeds.

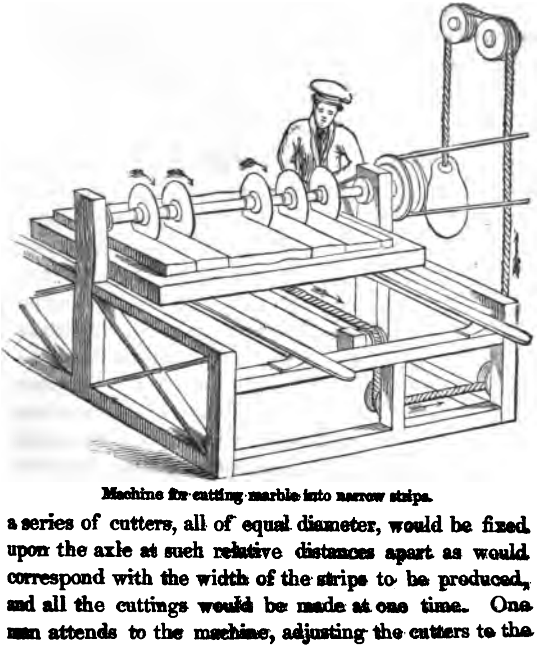
The saws here spoken of are rather unfortunately named. A stone-saw is not a saw at all. It is merely a piece of soft sheet-iron, with a blunt, smooth, straight edge, unprovided with teeth. Its action is not, properly speaking, to *cut* the stone, but to separate the particles of the material by friction. The effect is much increased by the addition of sand and water, the latter of which in some degree softens the stone, while the sharp particles of the former aid the frictive action of the saw; the small hard particles which constitute sand may indeed be deemed substitutes for the teeth of a saw. The quality of the sand is varied according to the nature and hardness of the stone to be cut; coarse sharp sand being used for soft kinds of stone, while very fine sand is better fitted for the harder stones. At many marble-works the sand employed is obtained from the neighbourhood of Croydon. It is well washed in large vessels, in order to free it as much as possible from extraneous substances; after which it is placed in a large brick receptacle covered with a roof, but open to the air, where it is kept till wanted. The cleanness of the sand employed is a matter of considerable importance; for if a small fragment of wood, or a grain so large that it will not penetrate (but rolls over) the stone, gets among the sand, the action of the saw is much impeded, and the removal of the obstacle is very difficult.

We will suppose that a block of Italian marble, eight or ten feet long, five or six wide, and one and a half thick, is to be cut into as many inch slabs as it will make, say sixteen. Sixteen saws are fitted into the frame parallel and equidistant, and the whole are lifted up by means of a windlass acting on the balance-weight above, to a height sufficient to allow the block of marble to be placed edge uppermost beneath them. The block is placed as nearly vertical as practicable, and is wedged and supported so as to remain firm. A very ingenious little machine is then suspended over the block, for supplying the saws with the requisite amount of sand and water. In the ordinary method of sawing by hand, a board is placed so as to slope towards the fissure made by the saw; and at the upper part of this board is placed a vessel of water, from which a small but constant stream is running down the board into the opening; a quantity of sand previously washed is also placed on the board at a little distance from the point where the water is running; and a portion of this sand is drawn forward by the workman into the running water by means of a stick with a hook at the end, and carried down gradually into the fissure made by the saw. But by the improved contrivance several saw-fissures are supplied with sand and water at once. An iron cistern, about two feet long, one high, and one wide, is filled with water; and in each side are fixed about twenty cocks. The water, slowly flowing from these cocks, falls into an equal number of little grooves formed in the bottom of a box filled with sand; and these grooves are so constructed that the sand and water flow out together at a number of little openings on one side of the box: these streams of sand and water being so directed as to flow each into one of the saw-fissures. As there are two grooved boxes, one on each side of the cistern, there are two streams of sand and water flowing into each fissure. This is one of those small pieces of mechanism frequently met with in our manufactures, in which more inventive ingenuity is often called for than in machines apparently much more important.

The saws being made to rest on the block, and the sand and water being arranged to flow into the fissures as soon as they are made, the saw-frame is set into reciprocating horizontal motion by a connection being formed between it and the working shaft of the steam-engine.

By a particular application of a parallel motion somewhat similar to that of Watt, the saws are moved in a strictly horizontal manner, the length of the stroke of each saw being about eighteen inches. When the saw comes to the end of its stroke it is lifted up a little by means of an inclined plane, so as to allow the sand and water to flow down beneath it in the crevice. As the cutting proceeds, the assemblage of saws descend by their own weight being a little greater than that of the balance; and the reciprocating motion continues till the block has been entirely divided into slabs.

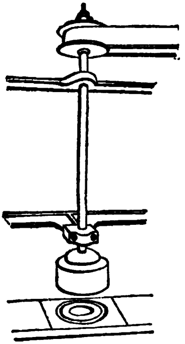
After a block of marble has been cut into slabs, it is for many purposes required to be reduced to the form of narrow strips, such as the several parts of a chimney-piece, or of a monumental tablet; or else into small pieces of various shapes. The large sawing-frames are not adapted for this smaller kind of workmanship, which is therefore effected in a machine called a 'ripping-bed,' represented in the annexed cut. This is a kind of table, twelve or fourteen feet long, six or seven wide, and three high; the flat of which is made of cast-iron. On this iron bed is placed one of plank, forming the top of the table; and on this the slabs which are to be cut into strips are temporarily fixed with plaster of Paris. A horizontal axle revolves a few inches above the table, and on this axle are fixed vertical cutters, consisting of circular pieces of soft iron about eight inches in diameter, the lower edge of which, while revolving, nearly touches the table. The iron bed on which the planking and the slab rest is connected, by means of pulleys, with a heavy weight, by which it is drawn slowly forward, the edge of the marble, thus forcibly drawn in contact with the edge of the cutter, is adjusted to its cutting action, and is pulled forward by the weight as fast as the cutting is effected. The axle, being several feet long, is adapted for the reception of several cutters at once, which may be so adjusted as to produce strips of any required width. Suppose, for example, it were required to cut a slab, three feet wide, into one dozen strips, all of different width:



Machine for cutting marble into narrow strips.

a series of cutters, all of equal diameter, would be fixed upon the axle at such relative distances apart as would correspond with the width of the strips to be produced, and all the cuttings would be made at one time. One man attends to the machine, adjusting the cutters to the axle, arranging the marble on the bed, adjusting the balance-weight to the work required to be effected, and keeping up a constant supply of sand and water at the fissures which the cutters make in the marble.

The form of this machine adapting it only to make rectilinear cuts, the production of a curve requires other arrangements. One machine for effecting this, for circles of large dimensions, consists of a flat bed capable of receiving a slab six or eight feet in diameter, in a horizontal position. Above this is a vertical pillar, to the lower end of which are attached four arms at right angles with one another, and all exactly equal in length. To the bottom of each arm is fixed a piece of iron, such as the saws are made of, bent into a curve corresponding with the curvature of the circle to be produced. These pieces of iron are capable of being fixed at any distance from the centre, and the distance chosen in any particular instance depends on the diameter of the circle to be cut. When the arms revolve, the pieces of iron attached to their lower surfaces become cutters: each is capable of making a circular cut in the surface of the

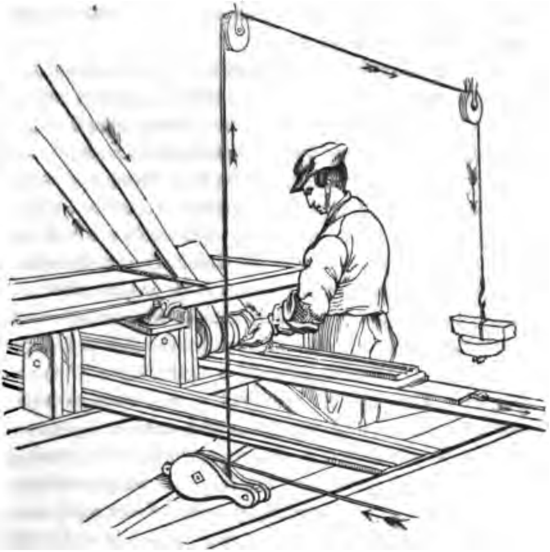


Machine for cutting small circles in marble.

marble during one rotation, and all acting in conjunction to produce a more speedy effect. The slab is fastened down to the bed with plaster of Paris, to keep it from shifting during the process of sawing; and the fissure is kept constantly wetted with sand and water by a man or boy in attendance on the machine. The revolving arms are connected with a balance-weight in such a manner that the cutters sink in proportion as the fissure in the marble becomes deeper, until at length a circular piece is entirely cut out of the slab. A smaller circular cutter acts on somewhat the same principle as the larger. A vertical shaft is set in rotation, to the lower end of which is attached a hollow cylinder of sheet-iron. The lower edge of this cylinder acts as a cutter, the marble to be cut being placed on a stand or bench immediately beneath it. Cylinders of different sizes are kept for circles of varying diameters, and their depth is such that three or four pieces of marble might be laid one on another, and all cut at once. The same means of fixing the marble to the bench beneath, of supplying the fissure with sand and water, and of elevating and depressing the cutters, are adopted in this as in the other machines lately described. Some years ago a contrivance, bearing a certain degree of resemblance to this, was devised for forming round pillars and hollow cylinders and tubes of stone; the cutting instrument in both cases being a cylinder of metal. By a small circular cutter of this kind, pieces of marble may be cut in great number, and with great accuracy, for mosaic or tessellated pavements.

But a mere circle, with a plain edge, is only one of the forms in which a curved piece of marble is required for ornamental purposes. The edge itself, or portions of a pillar or pedestal, may be required to present some architectural form, such as squares, rounds, hollows, &c. To give this form to a piece of marble a lathe is employed, differing little from the common turning-lathe. A small block of marble in a rough state, or a small circular piece of slab, as the case may be, is attached to the lathe, and set into rapid rotation by a shaft connected with the steam-engine; and a workman proceeds to give it the required form. This he does not effect with an iron cutter used with sand and water, nor with a mallet and chisel, but with long sharp-pointed instruments of steel, the points of which he brings in contact with the stone in the same manner as the turner uses his chisel. The stone flies off in small fragments by the use of the sharp-pointed instrument; and when a rough approximation to the shape has been thus produced, other tools, such as gouges, &c., are employed to complete the form of the piece of marble. Pillars and other objects of a similar kind could be worked by these means.

A few paragraphs back we described a machine called a 'ripping-bed,' by which a slab of marble could be cut up into strips. The strips thus produced are sometimes used in their plain form, after being polished; but they are more frequently diversified with mouldings, in a manner exemplified by the upright sides of a marble chimney-piece. These mouldings are worked by an ingenious machine called a 'moulding-bed,' bearing a good deal of resemblance to the 'ripping-bed,' so far as regards the flat table on which the marble is laid, and the position of a revolving axle a little above the table; but the cutters by which the mouldings are wrought are altogether different: they consist not of circular pieces of sheet-iron, but of masses of iron whose circular surfaces have been wrought into various forms, the counterparts of the different mouldings to be produced. When a strip of marble is to be moulded to any particular form, an iron

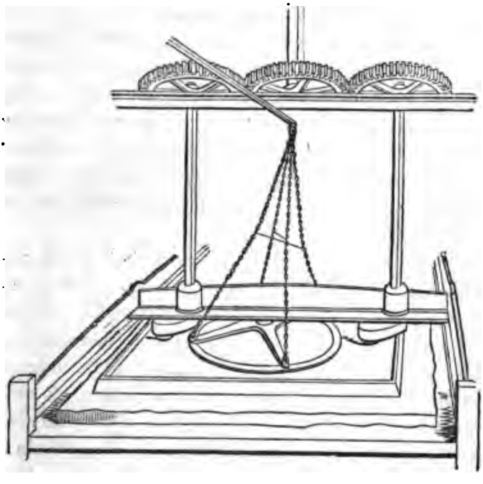


Machine for forming architectural mouldings in marble.

cutter corresponding with that form, or rather, the counterpart to it, is placed on an axle just above the bed of the machine, and firmly fixed in its place. The strip of marble is then fixed down with plaster of Paris to a board which is capable of being moved slowly forward by a rope and pulley, as in the other machines, at such a height as shall just allow the iron cutter to make the required depth of cutting. The cutter being set into rapid rotation, the marble is brought up to it, and is cut away by the action of the revolving iron. The marble advances onwards as fast as it is cut, and then presents a series of parallel mouldings on its surface, the counterpart of those in the cutter.

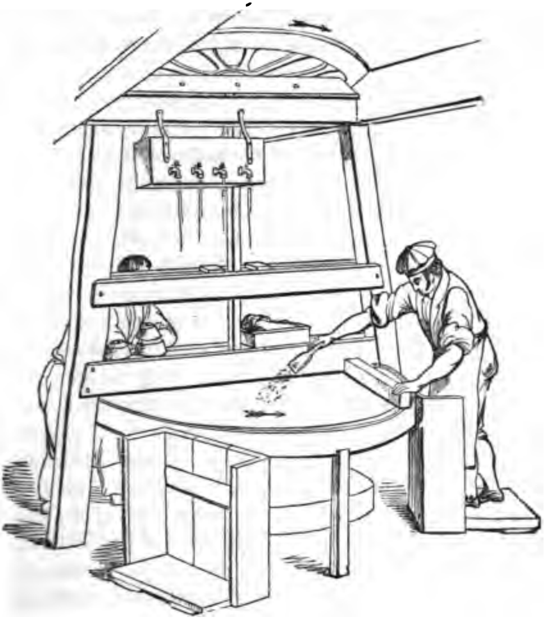
Having described several machines whose action is to cut the blocks of marble into smaller pieces of various forms, we may next speak of those whose office is to give a smooth and polished surface to the pieces so cut. The action of the cutters, whatever be their form, necessarily leaves a certain degree of roughness of surface; and if the cutting be made irregularly, the surface is not only rough, but uneven. Under all circumstances, therefore, a slab or piece of marble requires to be ground after it is cut. The means of effecting this at the marble-works are various, according to the size of the slab to be operated on. If the slab be large, a 'grinding-bed' is employed. This consists mainly of a very strong wooden bed or table on which the slab is laid, and of a large cast-iron plate whose lower surface performs the grinding process. The bed is subject to a very slow reciprocating or backward and forward motion, by means of rack and pinion work beneath; while the iron plate, which is suspended from above, has a very singular motion given to it, not exactly either circular or rectilinear, but a compound of both. The combination of these movements in the bed to which the marble is attached, and in the iron plate which is superposed on it, is such that the motion of any one point may be compared to the curves on an engine-turned watch. The object of this very ingenious contrivance is, that every part of the slab may be ground in the same degree and in the same manner, and that the movement of the iron over any particular part of the surface of the marble may be as varied in direction as possible. This process, like that of sawing, requires a supply of sand and water to aid the action of the iron; and the supply is effected in a curious manner. The plate is surrounded by a raised ledge, and is so pierced in various parts with round holes as to form a kind of shallow box with a perforated bottom; and being filled or partially filled with moistened sand, the latter finds its way down through the holes, and moistens the whole surface of the marble beneath the iron. The plate is capable of being elevated and depressed to different heights, to accommodate the thickness of the marble which may be placed beneath it.

The machine just described is particularly calculated for grinding large flat surfaces of marble, which it reduces to a plane almost mathematically correct. But for smaller pieces of marble, or the edges of slabs, another machine is employed, in which the grinding instrument, although arranged in a totally different manner, is still made of iron. A circular plate of iron, about five feet in diameter and two inches in thickness, is placed in a horizontal position, and connected with a vertical shaft or axle which passes through the centre. This axle, by the aid of intervening wheel-work, is set into rotation, and in its turn rotates the iron plate. The lower surface and the edge of the plate are hidden, but the upper surface is open; and being at a height of about three feet from the ground, it forms a convenient bed or bench at which the men may work; it is in fact an iron work-bench revolving in a horizontal direction. This 'circular grinding-bed,' which the workmen—with the peculiar nomenclature of which most workmen are so fond—call a 'roundabout,' is moistened with sand and water; and any pieces of marble which are to be ground by its aid are pressed down firmly upon it. The iron surface has the same effect on the marble in this instance as in the former, the difference being in the kind of motion given to the iron, and in the iron being beneath the marble instead of above it.



Machine for grinding large surfaces of marble.

The action of a surface of iron, used as in the two machines just described, is not to polish the piece of marble exposed to it, but merely to bring it to a perfect level, by removing all saw-marks and other irregularities of surface. But as one of the chief beauties for which marble is admired is the brilliant gloss which its surface presents when highly worked, the slabs or strips, after being ground by one of the two machines described

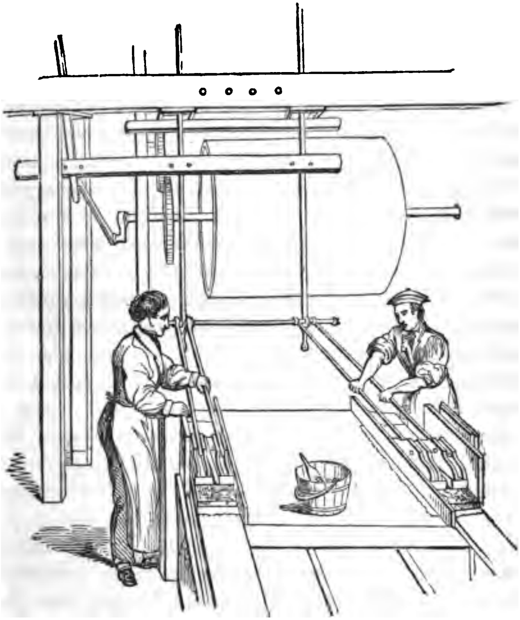


Rotating Slab for grinding marble.

above, are carried to a polishing-machine, or 'polishing-bed.' This machine is about twelve feet long, four or five wide, and three high. It consists of a flat bed on which the piece of marble is laid, and mechanism for working the polishing instruments. Each of these latter is about two feet long and four inches wide, formed of lead or some other heavy substance, and faced at the bottom with a layer of a peculiar kind of felt, adapted for the polishing of marble. Each polisher is connected by means of a long handle with the working machinery of a steam-engine, by which it acquires a backward and forward motion over the surface of the marble; and the arrangement is such that several polishers may be wrought at one time. All flat surfaces of marble, whether large slabs or narrow strips, may be polished in this way.

There are, in most worked specimens of marble, whether articles of furniture or of decoration, numerous small pieces which cannot be conveniently or profitably prepared by the machines which have lately engaged our attention. This is especially the case where any elaborate carved-work forms part of the design. If a small piece of marble is to be cut in a manner which does not require the aid of the machines, a man uses a kind of small hand-saw, formed, like the larger saws, of a piece of soft iron without teeth. This piece of iron is fixed into a handle, and it is used nearly in the same manner as a common saw; the workman keeping the fissure in the marble constantly supplied with sand and water, The process of grinding small pieces of marble by hand is in like manner a miniature representation of the analogous process as effected by machinery. Small pieces of iron, attached to wooden handles of a convenient shape, constitute the grinding-tools, which are used with sand and water.

The chisel and mallet are tools of which we have not had much occasion to speak; but they are much used in the finer and ornamental parts of the process. This is often very slow and tedious work. The piece of marble to be carved is placed upon a bench; and the workman, provided with chisels, gouges, and pointed instruments of various shapes, chips away the marble until he has formed the required device or pattern. Foliage, groups of figures, and indeed all patterns in which varying undulations of surface occur, are produced by these means. At one of the large London establishments black marble from Ireland is frequently wrought. This marble, brought from a quarry near Galway, is perfectly spotless, as black as jet, and susceptible of a very high polish; and as the blocks procurable from thence are among the largest which have ever been brought to England, the marble is capable of being applied to a great variety of purposes. A visit to the British Museum will show that our quarries are capable of supplying black and coloured marbles of great beauty. In the New Mineralogical Gallery are two tables, one presented to the Museum by Mr. Martin, and the other, in 1838, by the Duke of Rutland. The former consists of a richly variegated green and white serpentine marble, brought from the quarry of Ballinahinch, near Galway. The latter consists of two kinds of marble; the frame-work, legs, and bottom plinth of the table being of black marble, brought from Bakewell in Derbyshire; and the top being composed of a very curious sponge-coloured slab of stalagmitic marble, from Hartle in the same county. If the means were attained for working up these fine marbles in an expeditious and economical manner (and the patent machinery seems calculated to aid in producing this result), the more extensive use of our home quarries would in all probability follow.



Marble-polishing.

All the pieces of marble which have passed through the hands of the carver require to be ground and polished before the beauty of surface can be developed. This is effected by using small pieces of different substances, such as cast-iron, gritstone, smooth stone, and slate, shaped so as to suit the diversities of ornament, and rubbed over the marble until the latter is brought to a fine surface. These are processes which it is not probable machinery will ever be made to perform. Instead of expressing any surprise at this circumstance, we cannot but admire the ingenuity which could effect so many different processes by machinery: the cutting of slabs from the block; the cutting of strips from a slab; the cutting of various-sized circles; the cutting of architectural mouldings in a slip of marble; the grinding of a large slab by one machine, and of small pieces by another; the polishing of the pieces thus ground; and the adjustment of machinery by which all these processes are performed through the agency of one working shaft of the steam-engine—require no small share of inventive talent.

# CHAPTER II.

## GLASS-MANUFACTURE:

### *Flint-Glass.*

THE manufacture of glass is perhaps one of the most interesting presented to the notice of readers, not only for the beauty of the material produced, but also for the remarkable modifications which the ingredients undergo in the operation, and for the manual dexterity shown in the processes. Dr. Johnson, who was not much accustomed to allude to such subjects, placed in a striking point of view the claim which glass and its manufacture have to our attention. He says:—"Who, when he first saw the sand or ashes, by a casual intenseness of heat melted into a metalline form, rugged with excrescences and clouded with impurities, would have imagined that in this shapeless lump lay concealed so many conveniences of life as would, in time, constitute a great part of the happiness of the world? Yet, by some such fortuitous liquefaction was mankind taught to procure a body, at once in a high degree solid and transparent; which might admit the light of the sun, and exclude the violence of the wind; which might extend the sight of the philosopher to new ranges of existence, and charm him at one time with the unbounded extent of material creation, and at another with the endless subordination of animal life; and, what is of yet more importance, might supply the decays of nature, and succour old age with subsidiary sight. Thus was the first artificer in glass employed, though without his knowledge or expectation. He was facilitating and prolonging the enjoyment of light, enlarging the avenues of science, and conferring the highest and most lasting pleasures: he was enabling the student to contemplate nature, and the beauty to behold herself."

Many opaque substances are capable of assuming a form more or less vitreous or glass-like; such as earths, some acids and salts, and metallic oxides. In porcelain we see an example of partial vitrification; for the granular texture is exceedingly fine, and a slight translucency is produced. But complete vitrification never results until after the fusion or melting of the ingredients; and we know of no means by which porcelain clay or any other earth may be melted in its simple state. But when two kinds of earth are mixed together, or, still better, when a siliceous earth is mixed with certain crystalline salts, perfect fusion may be produced, and a nearer approach to transparent glass may result. Again, certain metallic oxides may be made to assume a vitreous form, and, when mixed with silex, to produce a glass possessing valuable properties. We may thence regard glass, generally speaking, as resulting from the mixture and fusion of these three kinds of ingredients; and the purpose fulfilled by each may be thus understood:—the siliceous substance is the vitrifiable ingredient; the salt or alkali is the flux, by mixture with which the silex becomes fusible; and the metallic oxide, besides acting as a flux, imparts certain qualities whereby one kind of glass is distinguishable from another.

Such is the nature of vitrification, a process which, if we may judge from the researches made within the last thirty or forty years in Egypt, and the discovery of the mode of deciphering the hieroglyphics so profusely displayed on Egyptian monuments, was known in very remote ages. Sir J. G. Wilkinson ('Manners and Customs of the Ancient Egyptians') adduces three distinct proofs that the art of glass-working was known in Egypt before the exodus of the children of Israel from that land, three thousand five hundred years ago. At Beni Hassan and at Thebes are paintings representing, in a very rude form, glass-blowers at work; and from the hieroglyphics accompanying them, it is found that they were executed in the reign of a monarch who occupied the throne at about that period. Again: images of glazed pottery were common at the period under consideration, the vitrified quality of which is of the same quality as glass; and therefore the mode of fusing, and the proper proportions of the ingredients for making glass, must have been already well known. Lastly, Sir J. G. Wilkinson adduces the instance of a glass bead about three-quarters of an inch in diameter, which Captain Henvey found at Thebes, and which contains in hieroglyphic characters the name of a monarch who lived fifteen hundred years before Christ.

The knowledge of the manufacture probably travelled from Egypt to Greece, and thence to Rome and modern Europe; and successive improvements have not only brought the art to a high degree of excellence, but have led to its subdivision into several kinds, such as flint-glass, plate-glass, window-glass, and green or bottle-glass making. These four we will consider in succession, beginning with *flint-glass.*

There are flint-glass works scattered in many different parts of the country, including London. These establishments generally comprise numerous buildings and rooms; such, for example, as a horse-mill, for grinding old melting-pots, as one of the ingredients in the manufacture of new ones; a room wherein ground or powdered clay is mixed and kneaded into a working state; another in which the pots are made; others for drying the manufactured pots; rooms for storing, washing, and preparing the alkaline salts; others for washing and drying the siliceous sand; a mixing-room, wherein the sand, alkali, and oxides are combined; coking-ovens, or furnaces for converting coal into coke; the glass-house with its working-furnaces, pot-furnace, and annealing-oven; glass-cutting and glass-engraving shops; and others for subsidiary purposes: the whole being separated more or less by open yards and passages. The routine of operations in these departments will come successively under our notice.

In describing the vitrifiable qualities of various materials, we used the most general terms, in order to include all kinds of glass within our remarks: but it is necessary now to state the restrictions which are required in practice. Although most earthy substances may, by peculiar treatment, be wholly or partially vitrified, yet *silex*, or *flint*, is that which possesses the most valuable qualities. Again, although many alkaline and saline substances might be used as fluxing materials, yet soda and potash, in one or other of their forms, are those generally employed by the glass-maker. Lastly, although many metallic oxides might be similarly vitrified, yet oxide of lead is that which is most frequently employed. This being premised, we may state that the materials for flint-glass are nearly as follow:—One part of alkali (carbonate and nitrate of potash), two parts of oxide of lead, three parts of sea-sand, and a minute portion of the oxides of manganese and arsenic.

The term 'flint-glass' is given because flints were formerly employed as the siliceous material: they were made red-hot, and plunged into cold water, whereby they were so fractured and disintegrated as to be easily ground to powder. Sea-sand is, however, now found to answer the same purpose, at a less expenditure of time and trouble. The sand employed is obtained from the sea-shore at Lynn in Norfolk, and at Alum Bay, Isle of Wight; the kinds brought from hence being superior to most others. A few years ago, a portion of sand brought from Australia as ballast was found to answer the purpose of English sand, and was indeed expected to be superior; we believe, however, that the qualities of the three kinds are now ranked nearly on a level.

The sand, being impure when brought to the works, is conveyed to an upper room, and thrown into a trough containing water. This trough is capable of being closed, and is fixed on horizontal pivots, whereby a rocking motion can be given; and the sand, being thus driven from side to side in the water, and stirred with a spade, loses some of its impurities. The dirty water is emptied into a channel in the floor of the room; and the same process is repeated seven or eight times, until the sand becomes perfectly clean. It is then placed in a trough over an oven, through holes in which it passes, when partially dried, into the oven beneath, and, when dried, leaves the oven in the state of fine, glittering, white particles.

With regard to the alkali employed, there are reasons why potash, in the form of carbonate, is preferable to other kinds; the carbonic acid being, however, dissipated during the melting, and leaving the potash in a pure state. The carbonate of potash is obtained from Canada and the United States, and requires a process of washing previous to use. It is conveyed to an underground apartment, in which are washing-bins, settling-pans, evaporating-pans, and other necessary apparatus. The state to which the carbonate is brought by the process of cleansing is that of fine white grains, differing but little, to an unpractised eye, from the prepared sand.

Oxide of lead, both in the form of litharge and of minium, or red-lead, is employed in flint-glass for the following reasons:—it is a powerful flux, enabling the sand to melt more readily, and it gives the glass greater density, greater power of refracting light, greater lustre, greater resistance to fracture from sudden heat and cold, and greater ductility during the working. If there be too much of this material, the glass becomes inconveniently soft.

The other ingredients in flint-glass, which are very small in quantity, are used as purifying and bleaching agents; and, as well as the oxide of lead, require but little preparation on the part of the glass-maker.

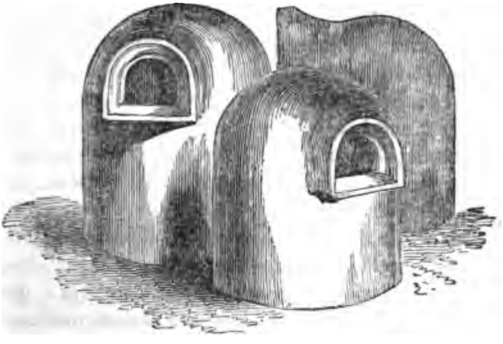
Let us assume that these several ingredients are in a sufficiently prepared state. They are taken to the 'mixing-room,' which contains several long bins or boxes;

and after being weighed in proper proportions, the ingredients are sifted, mixed in the bins, and brought to a state fit for the melting-furnace. Here we must leave them for the present, remembering that the state in which the ingredients are put into the melting-pots is that of a salmon-coloured powder, the red tinge being given by the oxide of lead.

The melting-pots, and their mode of preparation, now deserve our notice. The reader will not be surprised to hear that the manufacture, drying, and baking of the glass-pots are important processes; since one pot, when filled, contains sixteen hundredweight of glass, the preservation and proper melting of which are essential to the subsequent labours of the glass-worker.

There is a particular kind of clay, brought from Stourbridge in Worcestershire, which seems better calculated than any other as a material for the glass-pots, and which is dug from the soil in a hard state, ground fine, barrelled, and sent up to London. The broken or worn-out pots are likewise found to be useful when employed in combination with new clay; four parts of new clay being mixed with one part of old pots, ground by a horse-mill, and sifted to fine powder. The mixed ingredients are then either kneaded together by machinery, or are trampled by the naked feet of men, according to the establishment where the operations are conducted.

The services of the ‘pot-maker’ are now called for. The melting-pots for flint-glass are not moulded, but are built up piecemeal, each piece being rolled into a cylindrical form, and laid in a curve on preceding rolls. If we could imagine a boy’s grotto to be built of these clay rolls instead of oyster-shells, we might form an idea of the potter's operations, with this important addition, that every roll of clay is so thoroughly pressed and squeezed as to expel all the air from between the rolls, and to form a uniform and thick wall or crust. The manipulations of the potter are aided by a few simple tools; and, keeping four in progress at once, working a little on each in turn, he completes the four in six days. Few persons, probably, on hearing of a 'melting-pot,' would imagine the weight and bulk of those here alluded to. The weight of clay required for one pot is nearly one thousand pounds; and the dimensions of the finished vessel are about three feet in height, two and three-quarters in diameter, and from two to three inches thick. The shape is nearly cylindrical, with a hemispherical top and a flat base, and there is only one opening, about eight or ten inches in diameter, at the upper part of one side.



Pots for melting glass.

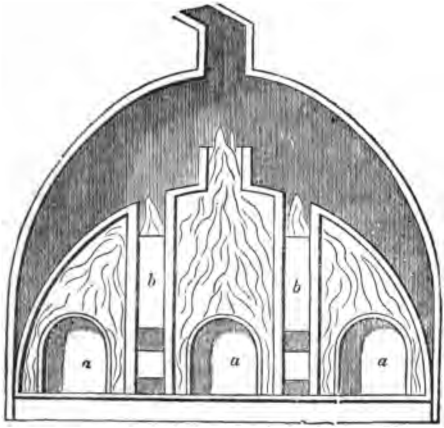
The longer these pots can be left before they are used, the better; consequently it is important to keep a considerable number on hand. The pots are kept in a large room for several months, during which time the evaporation from the damp clay is considerable,. and is allowed to go on very gradually, in order to ensure an equable state throughout the thickness of the pot. When the drying is effected, the pots are taken as wanted to an adjoining room, kept at a higher temperature, and are then placed in the 'pot-arch.' This arch is a small furnace capable of containing two or three pots; and the pots are there exposed for five days to a very intense heat.

The ingredients are prepared; the melting-pots are made and hardened; and it is now time to visit the 'glass-house' itself—the part of the building to which all the others are subsidiary. This is generally a spacious room, fifty or sixty feet square, with an earthen floor, bounded by brick walls, lofty and dimly lighted, and covered by an iron or tiled roof. This is the shell or crust, the kernel of which is the melting-furnace. The form and size of the furnace differ in different works, but in one establishment in London each furnace (there being two) is a circular dome, about fifteen feet in diameter and the same in height; and its internal construction may be understood by supposing two basins, one shallow and the other deep, to be inverted and placed one on another, the shallower one underneath. The inner basin encloses a space containing the pots, the fuel, and the flame and smoke arising therefrom; this flame and smoke reverberate from the vaulted roof, and pass up through flues into the cavity between the two basins, whence the smoke passes, by a bent pipe, into the chimney. All is constructed of brick, and lined with clay capable of resisting the fiercest heat.

The fuel for this furnace is laid on an iron grating in the middle, in connection with which, and beneath the glass-house, is a series of passages running in various directions to the extent of some hundred feet, and intended to furnish the channels for a powerful draught, which, passing upwards through the grating, keeps the fuel in an intensely ignited state. The roof of the inner dome of the furnace is about five or six feet from the ground; and the flame and heated air, reverberating from this roof, maintain a very high temperature within the internal area.

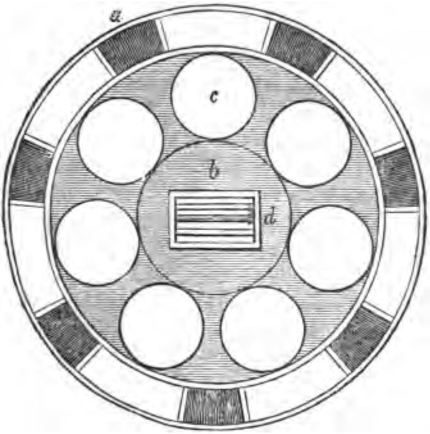
Formerly, the fuel employed used to be coal, but it is now found that in London many advantages result from employing oven-burned coke instead; and some of the glass-houses have conveniences at hand for making coke.

The melting-pots being of large dimensions, openings or arches of sufficient size are left in the sides of the furnace, to allow of the pots being introduced; after which the openings are bricked up. A pot, when once introduced into the furnace, is seldom removed until worn out; but as the average duration of a pot is not more than two or three months, these removals frequently occur. The withdrawal of an old pot and replacing it with a new one is called 'setting a pot,' and constitutes the most arduous and indeed fearful operation of the glass-house, and the one to which the men are wont to refer as proof of their power of heat-endurance. It frequently happens that the old pot breaks, and the pieces, becoming partially vitrified, adhere to the bottom of the



Section of the interior of a Glass-furnace. *a*, the pots; *b*, flues.

furnace: in such case the men stand in front of the fiercely heated openings, and dig up and remove the broken fragments of pot by means of crow-bars and other instruments. While the removal of the old pot is in progress, the new one is kept at a white heat in the 'pot-arch,' a pot-furnace within a few yards of the melting-furnace; and when the transference is to take place, the door of the arch is opened, a low iron carriage is wheeled in and tilted so as to lift up and draw out the pot, and the latter, at a glowing white heat, is wheeled to the furnace, and there deposited in its proper place. When the adjustment is properly made, the opening is immediately bricked up. The temperature to which the men are exposed in this operation (which sometimes takes



Ground Plan of Glass-furnace. *a*, flues; *b*, seague, or ground on which the pots *c* are placed; *d*, grate-bars.

several hours) may be imperfectly imagined when we remember that the other pots in the furnace may at that time be at a perfectly white heat.

In some kinds of glass-manufacture open melting-pots are used, whereby the fusion of the ingredients is effected in a shorter time. But flint-glass is liable to be injured by the carbonaceous and gaseous matters arising from the fuel, and therefore the pots are covered in. Each pot is so placed in the furnace, that the mouth shall be directed outwards; and this projecting mouth is so bricked and clayed round as to prevent the escape of flame. By this arrangement every part of the pot, except the mouth, is surrounded by a fierce heat;

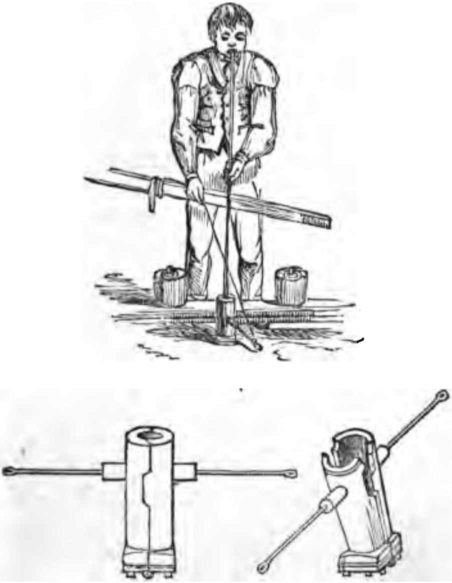
and although, on looking through this orifice from without, a fiery whiteness is seen, yet this results from the interior of the pot, and not from the interior of the furnace itself, the latter being entirely shielded from view.

Such is the melting-furnace, provided in this way with seven pots; and we now follow the routine of processes connected with the melting.

The management of a glass-house, in respect to *time*, is somewhat curious and worthy of note. The filling and emptying of a melting-pot are in general so managed as to occupy one week. On Friday morning the necessary arrangements for filling commence. The mixed ingredients are brought to the furnace in wooden vessels, and then thrown into the pots by means of shovels, through the openings before alluded to. About four hundredweight is put into each pot; the mouth is closed; the fire kept burning strongly; and the ingredients allowed to sink and melt. Three or four hours afterwards, the hole is again opened, another equal supply thrown in, and another equal space of time allowed to elapse. This is repeated four times, until each pot contain its full quota of about sixteen hundredweight. When all the pots are filled, every orifice is stopped up, the fuel is urged to vivid combustion by increased draught from beneath, and the ingredients remain throughout Saturday and Sunday exposed to an intense heat. At stated intervals a small opening is made, and a little of the 'metal' (as the glass is technically termed) is withdrawn to test its progress. In some glass-works a considerable quantity of scum rises to the surface of the glass while melting; but there is not much in a flint-glass furnace, on account of the purity of the materials, and this little is removed by skimming.

On Monday morning all is ready for the glass-workers, the pots are full of 'metal,' looking like liquid fire, and a large party of workmen assemble round the furnace. The mouths are opened, so as to afford access to the melted glass; and smaller holes are opened also, at which the working-tools are heated.

Flint-glass ware, such as drinking-glasses, cruets, decanters, lustres, lamp-shades, phials, &c., are made partly by blowing, partly by manual working, and, in a smaller degree, by moulding or casting, in a way which we will endeavour to describe. Let us first take the mode of making the common four-sided perfumery bottles. A man takes a hollow iron tube, about five feet long and half an inch in diameter, and, dipping one end into a pot of melted glass, collects a small quantity at the extremity. The glass appears like a projecting lump of red-hot iron, and, from its consistence (between that of treacle and of putty), is just able to be retained on the tube. The workman rolls the glass on a flat plate of iron, thereby giving it a cylindrical form, and pinches a part of it, by means of a small instrument, to form the neck of the bottle. He next inserts the end of the tube into a small brass mould lying on the ground, shuts the two parts of which the mould consisted, and blows through the tube. This double operation produces a curious effect; for while the air from the lungs, passing through the tube, makes the mass of glass hollow, the mould at the same time imparts to it the external form required. The mould being opened, the glass—now in the form of a bottle—is withdrawn. still adhering to the end of the rod, and is detached by a slight touch with a piece of cold iron. All this is done in about half a minute; and during the latter part of the process another workman is gathering and rolling a similar portion of glass, so that one mould serves for both. When the bottles are severed from the tube, they are taken up on the end of a heated rod by a third workman, who re-heats them (for by this time they are below red-heat), and by means of a few simple tools finishes the necks and mouths



Apparatus for making glass-bottles.

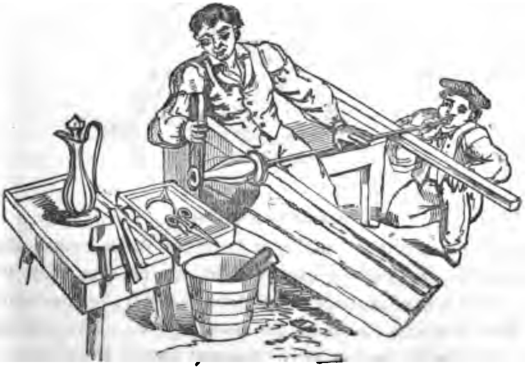
as fast as the other two can make the bottles. The lower of the two preceding cuts represents one form of mould used by the glass-worker; while the upper one represents the insertion in the mould and the blowing.

Let us next take an article of more elegant and complicated form, such as a claret-jug, and trace the progress of its manufacture. The workman, with a heavier tube than the one before alluded to, gathers a considerable quantity of metal; whirls it twice or thrice round his head to elongate the mass, rolls it on a flat iron plate to give it a regular shape; and blows through the tube from the other end, to make the glass hollow. The rolling and blowing having been repeated two or three times, another workman receives it and sits down in a chair having two flat parallel arms sloping downwards. Then,

Preparing for glass-blowing.

Glass-blowing.

resting the tube on these arms, he rolls it backwards and forwards, to keep the glass from bending; and a boy,



Forming a glass-vessel.

stooping down at the other end, blows through the tube, whereby the mass of glass is maintained hollow. By the aid of an elastic instrument, shaped nearly like sugar-tongs, the workman brings the mass into form, rolling the tube continually, and heating the glass frequently to preserve the proper consistence. Another workman, called the 'footer,' then brings a little melted glass on the end of a rod, and applies it to the end of the blown mass, to which it instantly adheres. This is soon shaped into a foot; and the whole is transferred from the tube to a rod called the 'punty,' the latter being made to adhere to the foot of the vessel by a little melted glass, and the tube being detached by a touch with a piece of cold iron at its junction with the glass. The glass thus transferred, the making of the upper part of the vessel

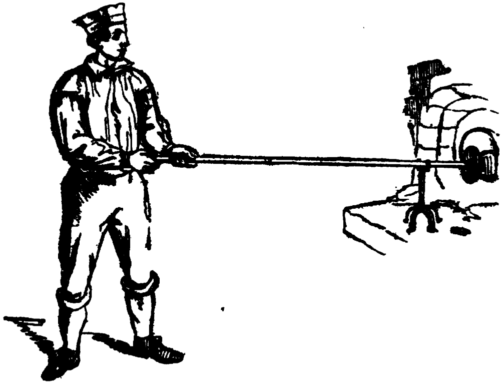
Cut-glass Jug.

proceeds. With the aid of scissors, a piece of glowing glass is cut off, so as to allow of a depression for the lip of the jug, and the edge is bent and curved with a dexterity altogether beyond the scope of description. Sometimes one prong, sometimes both prongs of the tongs are inserted in the mouth of the jug, and the internal cavity, as well as the external surface of the jug, are gradually modelled into shape. An attendant workman next brings a smaller mass of melted glass on the end of another rod, which is attached to the vessel, and curved in the form of a handle by a few delicate manœuvres.

The rapidity with which these operations are effected almost baffles the eye of a spectator. The glass is in such a medium state between a solid and a liquid, that while, on the one hand, it would drop from the tube if not kept rotating, it is, on the other, capable of being pulled, twisted, stretched, cut, pressed, and worked in various ways. No mould, stamp, or press is employed in the manufacture of such an article, the whole being effected by the manual dexterity and accurate eye of the workman, aided by a few of the most simple tools. Great, indeed, is the surprise excited at seeing such an elegantly formed vessel manufactured in such a way in the space of ten or twelve minutes: we here allude to the making only, for in the figure (on the preceding page) the jug is represented in its finished or 'cut' state. The eye of the workman detects when the glass is becoming too cold for working, and he holds it for a few seconds at the 'working-hole,'—one of the pot-mouths. After every such re-heating, he sits down again, and rolls the tube on the 'chair-arms,' with the glass projecting over near his right hand.

In all vessels provided with a leg and foot, such as wine-glasses, the leg is formed of one dip of glass, and the foot of another, each in turn being attached to the body of the vessel, and worked into shape. In such articles as salvers, dishes, or shallow vessels generally, the workman, after having his mass of glass hollowed by blowing, transfers it from the working-tube to the punty: the hole left where the tube had been attached he gradually enlarges, by whirling, modelling, re-heating, and bending, until the glass expands to the wide flat concave form required. In any vessel to be provided with a handle, a lump of glass—in the pasty or rather semi-solid state to which we have before alluded—is attached at one spot, drawn out, dexterously curved, and attached also at another spot, an operation nearly as surprising as any in the manufacture, since the workman has no guide but the accuracy of his eye in suddenly forming the handle. In such a production as a lamp or chandelier shade, the mass requires frequent re-heating, on account of the large size attained; and whenever the mass of glass has to be thus repeatedly heated, a constant rotation is given to the tube or rod, to preserve a circular form in the article attached to it. While re-heating at the furnace, this rotation is maintained as much as on the 'chair-arms,' a resting-groove being placed in front of the furnace-mouth, for the support of the rod while rotating.

The ductility of the melted glass, or that property by which it is capable of being drawn out, is perhaps nowhere so strikingly shown as in the making of glass tubes, such as are employed for thermometers, barometers, &c. A workman collects a quantity of glass on



Heating the Glass at the furnace-mouth.

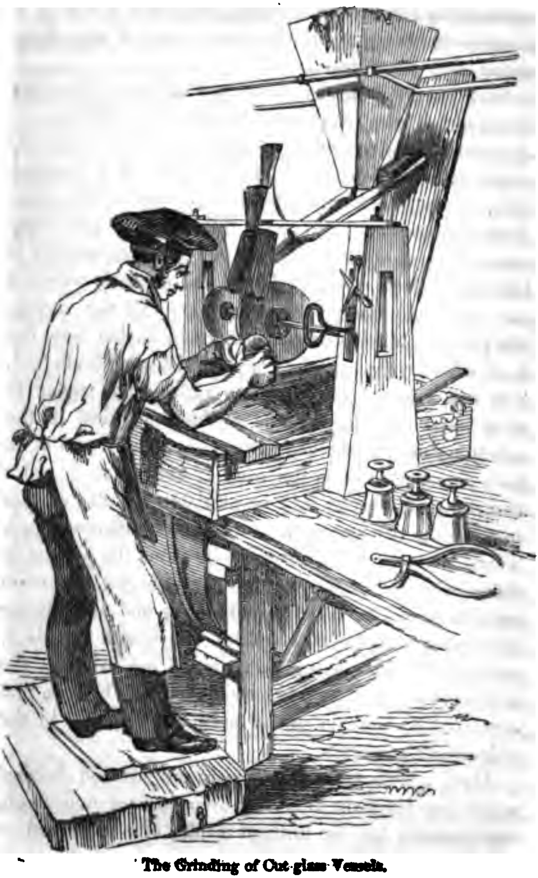
the end of a tube, rolls it on an iron plate into a cylindrical form, blows into it to form a cavity within, and holds it towards a second workman, who attaches a heated rod to the other end of the mass, to which it instantly adheres. The two men, standing opposite each other, then walk backwards, the glass elongating as they proceed, until a tube forty or fifty feet long is produced. This tube hangs down as it is formed, and rests on a ladder or frame laid along the floor of the glass-house: and by the time all the mass of glass is thus drawn out, a tube almost perfectly equable in thickness is formed, with a bore or perforation running through its whole length. The preservation of this bore is one of the most singular parts of the process, the elongated tube acquiring a bore of the same *form* as is given to the cavity in the mass of glass, however much reduced in size. In most thermometers the mercurial column is seen to be flattened, so as to be scarcely visible when viewed laterally. This flattened shape represents the form of the bore of the tube; and in order to produce it, the mass of glass, after having been blown hollow, is gently pressed on two opposite sides, whereby a flattening of the internal cavity is produced; while the external surface is again made cylindrical by re-dipping into the melting-pot. This form, *i. e.* flat within and circular without, is retained throughout the subsequent elongation, notwithstanding the vast diminution in the sectional area of the tube. Most kinds of glass-tubing, for meteorological, optical, or other purposes, are produced in a manner nearly analogous to that here described; the length of tubing being afterwards cut into convenient portions. Most persons have probably seen or heard of "Glass-working exhibitions," in which trinkets and toys are made in a very delicate and neat manner out of melted or softened glass. Although the glass is, in these cases, melted at a blowpipe instead of a furnace, yet the principle by which the exhibitor is enabled to proceed is the same as that developed in tube-making, and calls for our assent to the remark that "flint-glass possesses, at the working heat, a degree of tenacity and ductility not to be found in any other substance in nature."

We will now quit the melting-furnace, and watch the manufactured articles in the process of 'annealing.' The object of this process is to render the glass less brittle, and less liable to fracture from sudden alternations of temperature. If a glass vessel, made at the high temperature necessary for working, were allowed at once to cool in the open air, the surfaces of the vessel would cool and contract more rapidly than the interior substance, whereby the glass would be in an unequable state of elasticity, and therefore liable to fracture. We have seen a piece of thick glass-tube, which had been plunged while hot into cold water: the interior surface was cracked to such a degree as to appear like a surface covered with crystals. There are philosophical toys, known as 'Bologna phials' and 'Prince Rupert's Drops,' which are similarly treated, by being plunged into cold water while yet hot: the exterior becomes cooled and fixed before the interior has time to contract in a corresponding degree; the consequence of which is, that this unusual state of tension causes the whole to be shattered to atoms when the smallest incision or scratch is made on the surface. To avoid such an inconvenience as this, glass-ware is suffered to cool by very slow degrees.

This slow cooling takes place in an annealing-oven called a 'leer;' a name for which it would not perhaps be easy to furnish a reason, unless it be an instance of the Anglicised foreign terms used in a glass-house, and of which the 'punty,' or working rod, and the 'marver,' or iron plate, furnish examples—these two terms being derived from the French 'pontil' and 'marbre.' The oven has the form of a long flat arch, sixty feet in length or depth, five feet wide, and from one to two in height. Adjoining the door of the oven on each side is a furnace, by which a high temperature is maintained; but as there is no other heating-power, the oven experiences less and less of the heat as the distance from the mouth is greater, until, at the remote extremity, the temperature is scarcely higher than that of the surrounding atmosphere. Along the floor of the oven is a miniature railway upon which two rows of iron trays, called 'leer-pans,' travel.

Such being the arrangement, and all the operations being in full play, the annealing proceeds as follows:—As soon as a glass vessel is formed, a boy carries it, either on a wooden shovel or by means of a pronged fork, to the 'leer,' and places it in one of the pans. This continues until one pan is full; and the pan being then wheeled onward by means of a windlass, another is laid in its place, similarly filled, and similarly wheeled on; and so on, one pan after another. By this means, the pan first filled is drawn farther and farther from the heat, whereby the annealing or gradual cooling is effected. The time required for annealing varies from twelve to sixty hours according to the thickness of glass in the article manufactured; and matters are so arranged as to have similar articles in the oven at one time, in order that the same routine may be available for all; or else to make the two rows of pans travel with different speed. There are some annealing-ovens in which the process is differently conducted: they are much shorter, and more equably heated in the different parts; and after being filled with manufactured articles, the mouth is closed, and the fire allowed gradually to go out, whereby the whole oven loses its heat by slow degrees. The form first described is, however, found most advantageous in the flint-glass manufacture.

Many articles of flint-glass ware are deemed finished when they leave the annealing-oven, and are accordingly warehoused; but the brilliant display of a sideboard or dinner-table owes much of its attraction to the cut, or, if



The Grinding of Cut-glass Vessels.

the term be allowable, sculptured forms of the glass vessels. This cutting is effected after the vessels are annealed, and, in most glass-works, in a distinct building, by a process wholly different from those hitherto described. The glass-cutting room has several compartments for an equal number of men. In front of each workman is a thin wheel revolving on a horizontal axis; and above some of the wheels are vessels containing a mixture of sand and water, which drops through a small orifice in the bottom, and falls on the edge of the wheel. All the wheels are set in motion by steam-power, and each workman has the means of unfixing his wheel, and putting on another of a different kind. These wheels are of various sizes, and made of various substances, such as cast-iron, wrought-iron, Yorkshire stone, and willow-wood. The edge of the wheel is that part by which the grinding is effected; and different shapes and thicknesses are given to these edges, in order to produce different results.

The workman takes the glass, decanter, or other manufactured article, and holds it against the edge of the revolving wheel, by which the substance of the glass is ground down, and flat or curved surfaces produced. The vessel is held in various positions, according to the pattern required; accuracy of eye and steadiness of hand being indispensable in the workman. The iron wheels, with sand and water, are used for grinding away the substance of the glass; the stone wheel, with clean water, for smoothing the scratched surfaces; and the wooden wheel, with rotten-stone and putty-powder, for polishing.

By a modification of this grinding or cutting process the stoppers or stopples for bottles are ground, and the necks of small bottles made truly circular by attaching them to a kind of lathe, and applying small tools to the surface while revolving. The value of well-stopped bottles to the chemist renders this operation one of nicety and importance.

In addition to the cut surfaces of glass vessels, whereby such a lustrous play of colours is produced, the more costly articles are engraved, that is, devices are cut on the surface more delicate than can be produced by the cutting-wheel. The glass-engraver, seated at a bench before a small lathe, has at hand a series of little metallic disks or wheels, generally made of copper, and varying from an eighth of an inch to two inches in diameter. He attaches one of these to his lathe, touches the edge of the rotating disk with a little emery moistened in oil, and then holds the glass vessel against the edge of the disk, by which very minute scratches or indentations are produced. By dexterous changes in the position of the glass, and in the form and size of the disks employed, he combines these indentations so as to produce beautiful intaglios or sunken pictures.

This is strictly a branch of the Fine Arts, and as such places the engraver on a different level from the other workmen. Taste, both natural and cultivated, a knowledge of the external forms of natural objects, and a delicacy of eye and hand, are all required in this operation. A laudable attempt is now being made in England to diffuse among workmen a more extensive knowledge of the Arts of Design than has yet been possessed by them; and such operations as those of glass cutting and engraving afford an ample field for the display of this kind of knowledge.

The most profitable and important articles of flint-glass are such as are largely employed and have a current sale; but the costly and delicate articles occasionally produced call for great skill and inventive ingenuity. There is a kind of cut-glass in which the projecting parts of the pattern are coloured and the sunken parts colourless. These are produced in a remarkable way; for after the working-tube has collected nearly sufficient colourless glass from one pot, the mass is dipped into another containing glass which is coloured by the addition of certain metallic oxides, by which an external coating of coloured glass is given to the mass. When the blowing and modelling are completed, this exterior coating is, in the finishing process of cutting, ground away in some parts and left remaining in others, thus producing a singularly delicate effect.

Another kind of ornamental manufacture is the 'crystallo-ceramie,' or glass-incrustation, patented by Mr. Pellatt some years ago, and consisting of an opaque substance imbedded in a mass of colourless glass. A medallion or bas-relief, representing any device whatever, is moulded in a peculiar kind of clay capable of resisting the heat of melted glass; and the medallion is enclosed between two pieces of soft glass, or else is introduced into a cavity in the glass, from whence the air is afterwards extracted. The introduction of the medallion into the glass is the main difficulty in this process, and requires much skill and ingenuity, in order that no air-bubbles may exist between the two substances. When finished, and the external surface of the glass cut to the required form, the appearance of the imbedded medallion is singularly chaste and elegant; for the white clay, seen within the clear and highly refractive glass, presents an appearance nearly resembling that of unburnished silver. This branch of art, *i. e.* the incrustation of clay devices, was invented by a Bohemian, about sixty years ago; at a later period some French manufacturers incrusted medallions of Napoleon in this way, and sold them at an enormous price; but since the introduction of the art into England, under an improved form, a wide extension has been given to its applicability. Decanters, goblets, wine-glasses, lamps, girandoles, chimney-ornaments,

plates, door-handles, and other articles formed of flint-glass, have been ornamented in this way; the incrustations being arms, ciphers, crests, inscriptions, portraits, small busts, caryatides, or indeed any small objects capable of being modelled or moulded in clay. The incrustation may be painted with metallic colours, which will remain uninjured by the heat required in the process.

There is a mode of incrusting opaque ornaments or devices on the surface, instead of within the substance, of the glass. This is effected by adjusting the ornament in a brass mould, and blowing and moulding the glass to it; the details requiring considerable skill, but the principle being nearly the same as in the other process.

The astronomer and the optician obtain from the flint-glass manufacturer the materials from which their lenses are made. It has been ascertained that there is a certain state of the fused glass which is best calculated for optical purposes; and when the mass has attained this state, about seven pounds weight is taken up in a conical ladle and blown into the form of a hollow cylinder. This cylinder is cut open, and flattened into a sheet twenty inches long by fourteen wide, and from two to three eighths of an inch in thickness. In this form it passes into the hands of the optician, who cuts and grinds it to the shapes required for optical purposes. The masses of glass for large telescope lenses require a somewhat different process, and extraordinary care in the choice, preparation, mixing, and melting of the ingredients: indeed, the production of good glass for this purpose is one of the most uncertain things in the whole glass-manufacture.

# CHAPTER III.

## GLASS MANUFACTURE:

### *Window and Plate Glass.*

Although flint-glass is made to a considerable extent in London, by far the larger proportion of the other three kinds, *crown*, *plate*, and *bottle* glass, is made in the country, especially in and near Newcastle.

Whatever may be the origin or fitness of the term 'crown-glass,' the glass so designated is that with which windows are generally glazed in this country, and which is also generally employed for framed prints and drawings. It is always made in a circular form, rather thicker at the circumference than elsewhere, and having a knot or protuberant bulb in the centre. This is certainly a very unfortunate shape for such glass to assume; since, as the central bulb must always be cut away, and as the glass is nearly always used in a quadrangular form, there is a very serious amount of loss in cutting up the glass for use. The other kinds of glass, as we shall see further on, are not exposed to this disadvantage; but, on the other hand, there are counterbalancing advantages which lead to a much larger manufacture of crown-glass than of plate, broad, or sheet glass, and indeed greater than of all these taken together.

It happens in this as in most other departments of manufacture, that each firm adopts its own peculiar views as to the choice and proportion of the ingredients employed. And indeed this is especially observable in the glass manufacture; for it involves such a remarkable chemical union of heterogeneous substances, that it may be deemed an experimental art, the experience derived from past trials being made the ground for future ones. It will be sufficient, however, for our purpose, to say that the ingredients for crown-glass usually comprise the following:—clean white sand, soda or potash, lime, and a very small quantity of one or two other substances. For shortness we will say that the ingredients are sand, alkali, and lime: the first two really constitute the glass, while the lime acts as a flux to enable the others to melt and combine more readily.

This union of sand or flint with an alkali, as the chief circumstance involved in the production of glass, is observable in the legendary account of the discovery of glass as given by the early writers. According to this story, there was on one occasion a merchant vessel, laden with nitre (one form of the alkali potash), driven ashore on the coast of Palestine, near the mouth of the river Belus, a small stream running from the foot of Mount Carmel into the Mediterranean. The mariners, unable to procure stones to rest their cooking-vessels upon, used pieces of the nitre instead. The fire reduced the alkali to a soft state, and enabled it to incorporate with the river sand, forming together a stream of liquid glass. The circumstance was communicated to the inhabitants of the district, who availed themselves of the hint, and established a manufacture of glass. Whether or not we choose to place credence in this story, certain it is that alkali and sand, wherever found and however melted together, form the bases of all the glass with which we are acquainted.

Of these ingredients, the sand (as before observed) is obtained chiefly from the neighbourhood of King's Lynn in Norfolk, where a very fine and white sand is found on the sea-shore; and also from the Isle of Wight. It was not always usual to employ sand for this purpose, for flints used to be selected instead; as, however, it was found that sand answered the purpose, and saved the trouble of calcining and grinding the flints, the latter gradually became superseded by the former. The term *flint*-glass had its origin from this employment of flints in its manufacture. With regard to the alkali employed, this has been affected by the substitution of salt for kelp as a source of soda. In former times, the glass-makers used to employ large quantities of kelp, which they procured from Scotland; it was an impure carbonate of soda, which gave off its carbonic acid and its impurities by the action of heat, and entered into the composition of glass in the state of soda. But as now obtained from common salt, the carbonate yields a much larger amount of pure soda for a given price, and has thrown into shade the use of kelp for this purpose.

Before the ingredients are actually mixed in the melting-pots, they undergo a preparatory operation called *fritting*, the object of which is to fit them to form a more homogeneous compound. This is effected in a kind of oven, very shallow in proportion to its area. The sand is first washed clean, and exposed for several hours to the action of a strong heat; then, while hot, it is plunged into cold water, which splits the grains of sand to a still smaller size, and enables them to combine more readily with the alkali. The fine sand and alkali being then mixed together, the mixture is placed in the shallow oven, or 'calcining arch,' where it is exposed to a heat which brings it to the liquid state; and by being constantly stirred for some time while in this state, it undergoes considerable change: the moisture is driven off, the carbonic acid is expelled from the alkali, the carbonaceous particles are burned away, and the ingredients are brought into chemical union. The mixture, which now obtains the name of *frit*, is taken from the oven, spread out upon a plate of iron while yet hot, and is divided into large cakes before it becomes quite cold.

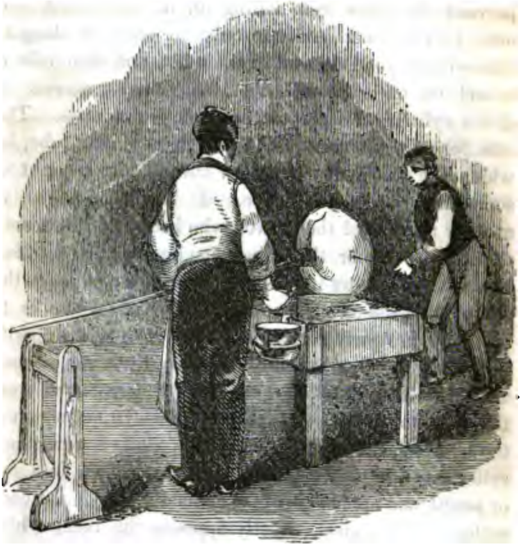
It is from this frit, then, that the glass is made. The frit is melted in pots of very large size, and requiring peculiar care in the manufacture: they are not exactly like those used in the flint-glass manufacture, but the resemblance is sufficiently close to render any further description unnecessary.

A crown-glass house is somewhat differently arranged from one for flint-glass. Exterior to the furnace a passage is left open, where the workmen take up their stations; and on the other side of this passage are the openings to numerous ovens or furnaces, wholly distinct from the central furnaces. If we therefore picture to ourselves a pathway going round a central furnace, and being itself bounded by other furnaces, we shall form some conception of the kind of place where the glass-makers work. To say that they are "between two fires" is only a part of the truth; they are between and adjacent to a dozen fires, and become exposed to the action of one as soon as they leave another. There is very little light in the glass-house except what is derived from the opened or partially opened mouths of the furnaces; and as the men go flitting past these fiery spots—now exposing their brawny figures to the full glare of the light, and now involved temporarily in shade—they form items in a picture replete with striking effects. If each man stood in one spot, and made a piece of glass by his own work, the picture would approach nearer to one of 'still-life;' but they are continually passing to and fro. A piece of glass goes from hand to hand, probably a dozen times in the process of making, travelling along from one furnace to another, and receiving at each spot and from each man some modification in its form. Heat, bustle, and dexterity are, in fact, the three features which attract our attention.

The frit is placed in the pots, together with a portion of 'cullet,' or broken glass; and both together are exposed to an intense heat, whereby they are melted into a liquid glass. The impurities rise to the surface, and are then skimmed off by the aid of an appropriate instrument. The glass (or 'metal,' as it is technically called) is not in a workable state when quite liquid; but by slackening the heat a little, the glass becomes slightly viscid, and is in that state fitted to undergo the remarkable operations which constitute crown-glass making.

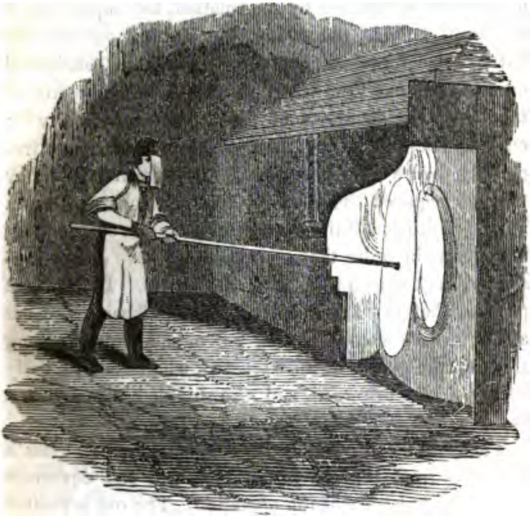
As each 'table' or circular piece of glass requires only a few minutes in making, but demands the services of several workmen, all place themselves in readiness to act their parts in the scene. The first man, called the *gatherer*, approaches one of the furnace-mouths and dips into the melted glass the end of an iron tube six or seven feet in length; he turns the tube gently round, until he has gathered a pound or two of pasty glass on its end; he allows this to cool a little; then dips it again, to increase the quantity; then allows this to cool a little; and so on, until he has gathered a mass of nine or ten pounds of the paste-like and fiery-coloured glass on the end of the tube, turning the tube all the time to prevent the glass from falling off it. He holds this mass perpendicularly downwards, to make it elongate somewhat beyond the end of the tube; and then rolls it to and fro on a smooth iron plate called a *marver*, to give a cylindrical form to the protuberant mass. The man (or an assistant) then blows through the tube, by which the glass is made hollow within, and brought to something like a pear-shape. It is then handed to another man called the blower, who heats it at the mouth of a furnace two or three times, and after each heating blows it and rotates it; till at length he so enlarges the size of the mass of glass and reduces its thickness as to present it in nearly a globular form. The side opposite to the tube is then slightly flattened, by being pressed against an iron plate; and the glass is transferred from the tube to a rod in a remarkably dexterous manner: the blower holds the tube horizontal, while another man collects a little melted glass on the end of an iron rod or *pontil*, and applies this to the middle of the flattened surface of the glass, exactly opposite the tube, which latter is immediately afterwards detached by touching the point of junction with a piece of iron wetted with cold water. This transference from the end of the tube to the end of the rod is effected so quickly and neatly as to form one of the prettiest parts of the operation.

We have, then, up to this point, a flattened globe of glass fixed to an iron rod at the flattened side, and having a small hole on the opposite side, occasioned by the detachment from the tube. How this is transformed into a flat circular sheet is the next point to notice. The workman holds the pontil so that the glass shall be exposed to the heat of a furnace, at one of the mouths or openings called by the men a 'nose-hole.' He rests the rod at one particular point on a bar which serves as a support or fulcrum; and keeps the glass rotating while exposed to the heat. As the substance of the glass becomes hotter and softer, it yields more readily to the centrifugal force engendered by the rotation: it becomes



Making Crown-glass.

every moment broader and flatter, deviating more and more from the shape of a globe. The hole which the tube had before formed, and which was at first only about two inches in diameter, gradually enlarges by the same force, until it becomes three inches—six—twelve inches in diameter; and finally, the whirling action so completely masters the previous condition of the glass, that the flattened and misshapen globe suddenly 'flashes' (to use a technical term) out into a circular sheet four or five feet in diameter, nearly equable in thickness in every part, and being still attached to the rod exactly at the centre.



Making Crown-glass.

This rapid succession of changes is to a bystander at once beautiful and inexplicable. The facility with which the pasty glass is worked into form, the hollowing of the mass by means of the breath, the maintenance of a particular degree of softness while exposed to heat, the transference from the tube to the rod, the steadiness of position maintained by the rotation, the expanding of the small hole in the centre, the flashing out into the flat circular form—all are very remarkable considered even singly, and form when viewed collectively one of the most striking series of operations connected with our manufactures. The glass changes hands more frequently than we have here noted; each man having by practice acquired the skill for one particular operation. It passes also round the central furnace from one opening to another, in order that each man may have a working-spot without interfering with the others. In the last process, that of 'flashing,' the heat and flame given out at the furnace mouth are very fierce, and throw a strong glare on the person of the workman, who stands partially behind a kind of screen, and who shields his face with a handkerchief or cloth.

The manner in which the circular table of glass is detached from the rod is not less neat and dexterous than the other parts of the operation. The rod is rotated for a few seconds after the glass has 'flashed,' at such a distance from the fire as to give the glass sufficient coolness to maintain its shape. The man then carries it a short distance, and places the glass down horizontally on a bed of sand, where the rod is detached from it in a moment by another man. The circular piece (having the 'knot' or 'bull's eye' in the centre) is then lifted up on a wide two-pronged fork, and placed upright in an annealing-oven. Here it is allowed to cool very gradually, whereby it becomes annealed, or loses some of the brittleness which would otherwise characterize it.

It will readily be understood that although a dozen men are thus engaged in making one piece of glass, there are many pieces under operation at the same time, each man taking up a new one as soon as he has handed over the previous one to the man standing next to him. There is thus a kind of endless chain, of which all the links are being made at once.

There is very little more which need engage our attention respecting crown-glass. The circular sheets, when cooled in the annealing-oven, are carried to the warehouse to be packed in straw in the wooden crates which are familiar to most persons. Sometimes they are packed in the circular form; while in other instances the circle is cut into two unequal pieces, that one which contains the bull's eye or knot being called a *table*, and the smaller piece being called a *slab*. According to the colour, trueness, and flatness of the glass, it is divided into four kinds or qualities, which bring different rates of price in the market. Although some of the circular sheets are five feet in diameter, yet, owing to the curvature of the edge and to the central knot, a rectangular piece measuring three feet by two is nearly the largest that can be obtained from them. Of the little instrument with which this cutting of the tables of crown-glass is effected, as well as the glass used by the glaziers generally, a few words may be said. It is a generally understood principle among mineralogists that the quality of *hardness* is tested by the power of one substance to cut or scratch another; and it is by the operation of this test that the diamond is found to be nearly, if not quite, the hardest body in nature. Glass is very hard, but the superior hardness of the diamond enables it to cut or scratch glass very easily. It is a singular fact, however, that the edge which cuts the glass must be one of the original edges of the crystal; an artificial edge will scratch but not cut; and hence a fragment of diamond which contains a natural edge is more valuable for this purpose than a large piece in which the edges are all artificial. If a fragment contain but one natural edge, the diamond is useless when that edge is worn away; but if it have several such edges, as soon as one edge is worn away another may be employed. The fragments employed do not weigh more than about one-sixtieth part of a carat each (one-twentieth part of a grain); and in order to fit them for use, they are fitted into wooden handles, consisting of a rounded piece of rosewood, flattened at the two sides to fit between the sides of the fore and middle fingers. The adjustment is effected in two modes. In the former or older of these, the diamond is set fast in a conical shoulder; and a difficulty arises in placing the diamond so as to cut, for it must always be held in a particular position with respect to the natural edges of the crystal. In the new or patent diamond, however, the jewel is so set in a brass socket at the lower end of the handle, as to have a little freedom of movement given to it, and this facilitates the holding of the instrument in the right position for cutting the glass on which it is placed.

Let us next take a similar glance at the manufacture of

### *Plate-Glass.*

A better name than *plate*-glass would be *cast*-glass, since the former is vague in its acceptation, whereas the latter expresses the mode of manufacture. This kind of glass is *cast* or *founded* while in a liquid state, and is totally independent of the process of blowing. There was formerly, however, a kind of glass which resembled plate-glass in its general qualities, and which was produced by blowing instead of casting; but this has been almost completely superseded by the cast-glass of modern times. Blown plate-glass, like crown-glass, can only be made of small dimensions; but cast-glass has been produced as large as fourteen feet long by eight or nine in width.

The plate-glass, or glass (whether cast or not) which was to serve for mirrors, was originally a very favoured manufacture. Whether this kind of glass was known in early times is still matter of conjecture; but its manufacture was carried on by the Venetians some centuries ago: so useful were the glass-makers regarded at one time at Venice, and so great was the revenue accruing to the republic from the manufacture, that, to encourage the men engaged in it, the senate made them all burgesses of Venice, and allowed nobles to marry their daughters; whereas, if a nobleman married the daughter of any other tradesman, the issue were not reputed noble. Again, in the early times of glass-making in France, the French government made a concession in favour of this manufacture, by decreeing that not only should no derogation from nobility follow the practice of the art, but that none save gentlemen, or the sons of noblemen, should venture to engage in any of its branches, even as working artisans. This limitation was accompanied by a grant of a royal charter of incorporation, conveying important privileges, under which the occupation became eventually a source of great wealth to several families of distinction.

The plate-glass manufacture in our own day is remarkable for the small number of establishments in which it has been centred. There are only four or five firms in England by whom plate-glass is made. It was seventy years ago that the first of these large works was established in Lancashire, and during the whole of the intervening period there have never been at any time more than four or five in operation: seldom more than three. Newspaper readers have often remarked that the London daily papers remain the same in number year after year; porter-drinkers find that the great London breweries remain pretty equal as to number year after year; and it may be that the necessity for great capital and great experience will point to the analogous state of the plate-glass manufacturer as well as to these. But be this as it may, the fact of the smallness of number is undisputed.

The plate-glass factories are buildings of remarkable appearance within: very large, quiet, and so dark as to appear gloomy to those unaccustomed to the place, except indeed when a plate of glass is being cast, at which time a vivid and brilliant glow is diffused around. One such may serve as a type of the rest. In a building of large size is a central furnace or group of furnaces, with a lofty open area extending three-fourths around it. Exterior to this is a series of annealing-ovens, several in number, the mouths of which are in what may be termed the wall of the room. Everything is on a much larger scale, and is more cleanly in its appearance, than in most crown-glass departments. The most conspicuous piece of apparatus is the *casting-table*, a carefully prepared plate of iron, with various mechanism to place it in any desired position. This iron plate measures sometimes seventeen feet by nine or ten, and gives a limit to the

Examining melted Plate-glass before casting.

size of the glass that can be made upon it. Suspended above or near the casting-table is the apparatus by which the melted glass is poured upon the table; and there are other arrangements for working the pasty glass before it solidifies. On the floor of the building a railway is laid, along which the casting-table is wheeled from one annealing-oven to another, since it is necessary that the table should be placed close to the oven into which the plate is removed for annealing after being cast.

In the furnaces which occupy the central part of this great room the glass is brought to a liquid state. In the selection of the ingredients, in the purifying of them for use, in the proportions of mixing, and in the completeness of mixture, more care is bestowed in the plate-glass manufacture than in any other. A large sheet of plate-glass is perhaps one of the most perfect and beautiful of manufactured products, and requires experience and dexterity in every stage of its manufacture: its colour, its freedom from air-bubbles and from coloured specks, its regularity or freedom from veins and wrinkles, its equability of thickness, its freedom from mist or cloudiness—all require the closest attention on the part of the manufacturer. As to the ingredients employed, they so far resemble those used for crown-glass as to comprise sand, alkali, and lime as the three principal ones; but the minute details in respect to proportions and additional ingredients are of great nicety, and concern only the manufacturers themselves. It will suffice for our present purpose to know that the above three ingredients form by far the larger portion of the body of the glass.

The ingredients, then, being *fritted*, or partially combined in small furnaces, are placed in the melting-pots, together with a portion of *cullet*, or broken plate-glass. These pots are, like those for crown-glass, made with great care in respect to their power of bearing heat; but in their shape, and in that of the furnace in which they are placed, there are points of difference corresponding with the difference in the mode of working. When the red-hot liquid lava (if we may so term it) has arrived at a particular state, it undergoes an examination, which may be taken as an instance of the caution observed in the manufacture. Three men take a copper ladle having a long handle, dip the ladle into the melted glass in the furnace, and convey it to a small flat slab or tray, on which the glass is poured out. One man holds the handle, while the other two support the bowl of the ladle by cross handles. The red-hot mass is so soon affected by the coolness of the air, that it assumes a thick pasty consistence when placed on the tray. A man then examines it, to see whether any slight difference of colour indicate defective spots: he knows from experience what are the causes of these spots, and in what way they will affect the purity of the glass when finished; he therefore removes them with the pointed end of a rod or tool, and leaves the rest of the mass in a uniform state. The mass is returned to the ladle, and the three men carry it back to the furnace. It is now put into different pots from those which before contained it, and thus these pots become filled with the successively examined portions. When the quantity has thus accumulated to the required amount for one casting (comprising several hundredweights) the pots are exposed to a heat sufficient to bring all the glass to a liquid state.

It may be well supposed that a recognised order is observed in all these preparatory arrangements, so that while one potful of glass is going through the later stages, others are passing through an earlier stage. Thirty or forty hours are required for the melting and proper combination of the materials. It is not exactly a liquid state which is most proper for the casting; but after the perfect melting has taken place, the glowing mass is allowed to lower its temperature a little, so as to acquire a slight degree of viscidity.

We will suppose, then, that this viscid state has been attained, and that the casting is about to take place. A group of fifteen or twenty men assemble round the casting-table, or between it and the furnace, each one having evidently a definite office to fill, at a particular spot and a particular moment. The *cuvette*, a vessel from which the glass is poured in the casting, remains in the furnace, of the same white-hot temperature as the liquid glass it contains; it having been filled by means of the ladle while in this situation. At the appointed moment, the cuvette is drawn out of the furnace by means of a crane; and the brightly glowing vessel is quickly swung round so as to be brought over the casting-table, very near the end which adjoins the annealing-oven. The foreman or director of the casting places himself in a particular spot; the men also take up their positions; and at a given signal the cuvette is tilted up so as to pour out its broad stream of golden lava on the casting-table beneath. A number of minor adjustments are then quickly made by the men, the principal of which consists in passing a heavy polished iron roller over the whole surface of the melted glass from one end of the table nearly to the other. This roller rests on two ledges or grooves equal in height to the intended thickness of the plate of glass, so as to spread out the ductile mass into an equable sheet: it is, in effect, a huge rolling-pin; and, like that well-known appendage to the kitchen, it gives a flattened form to a shapeless yielding mass. The appearances meanwhile, are exceedingly splendid. The building being very dark within, the glowing cuvette throws a strong light on the faces and persons of the workmen, producing effects of bold relief which Rembrandt would have loved to paint; and while the white stream is pouring down, the reflected light is still more intense. Then, when the iron roller has passed over the glass, the surface of the latter presents a beautiful play of brilliant colours, comprising every imaginable tint; caused probably by a temporary oxidation of the surface by the coolness of the iron.

The quantity of glass cast at once depends on the size of the table, and is such as will make a plate more or less within those dimensions. There are so many probable sources of defect, that it is never known until after the plate is made whether it is so uniformly good in every part as to be retained in its largest dimensions: if not, it is severed where the defects occur, and is sold in smaller pieces. As soon as the newly cast plate has solidified, the door of the annealing-oven is opened, and the plate of glass is dexterously thrust from the table into the oven. These ovens are very deep, so as to allow several plates to lie in them edge to edge. The oven is closed up very tightly after the glass is put into it; and there the heat is allowed to decline gradually for many days, so that by this slow cooling the glass may become annealed.

The ponderous iron casting-table will serve to supply all the annealing-ovens. It is wheeled on from one to another by means of the railway; and makes its circuit by the time the annealing is finished.

At this stage we quit the casting-house, and visit the building where the plates are ground and polished. Here everything is changed. The men are different, the buildings, the processes, the materials, the machines—all are so totally distinct as to appear like a different subject of manufacture altogether. In these buildings the rough plates of glass are brought to the brilliant state in which we are accustomed to see them. As they leave the casting-table, they are rough and somewhat undulated, and wholly destitute of polish. They are cut to a rectangular form by means of a diamond, and conveyed to the grinding-room. This is a large room filled with machines in a constant state of rotation; and the sand and water which are dripping around show that the process going on is not by any means a cleanly one. The plates of glass are cemented by means of plaster of Paris to flat beds or frames, and are in this state inverted one over another, so as to have the two plates of glass in contact. The upper one is so connected to machinery moved by a steam-engine as to have a rotatory motion given it; and by introducing between the plates some wetted sand or ground flint, each plate grinds the contiguous surface of the other. The plates are cast very much thicker than they are wanted for use, in order to admit of the surfaces being ground away till no defects appear; and this diminution sometimes extends to one-half the thickness of the plate. From time to time the flint and water are sprinkled on; and from time to time also the plates are removed to see how the process is going on. When one surface of each plate is ground, the plate is separated from the frame, and reversed, so as to expose the opposite side; and these new surfaces are then similarly ground one against the other.

The effect of this grinding is to remove all inequalities and to bring the glass to a perfect level; but it is not only deficient in polish, it is covered with scratches from the fragments of flint, and these scratches must be removed before the glass can be polished. To effect this emery-powder of several degrees of fineness is employed; the coarsest first, and so on to the finest. The smoothing by means of this emery-powder has the effect of removing all the scratches, and of producing a delicate dead-like appearance of surface, but without anything which can be termed a polish. This stage of the work is done by a large number of women, working on stone benches. During these successive stages of progress the two plates are made to grind each other, the upper one moving over and upon the lower; the intervening wetted emery-powder being changed from time to time, until a quality of exquisite fineness is finally used.

The plates are then conveyed to a building containing numerous polishing-machines of remarkable construction. Each plate is laid down on a flat bed, and is rubbed over every part for a long period with a system of rubbers or polishers kept in motion by steam power. These polishers consist of oblong pieces of wood covered with cloth on which a kind of polishing-paste is laid; and it is by repeated rubbing with these small pieces of apparatus that the plate receives its final brilliancy.

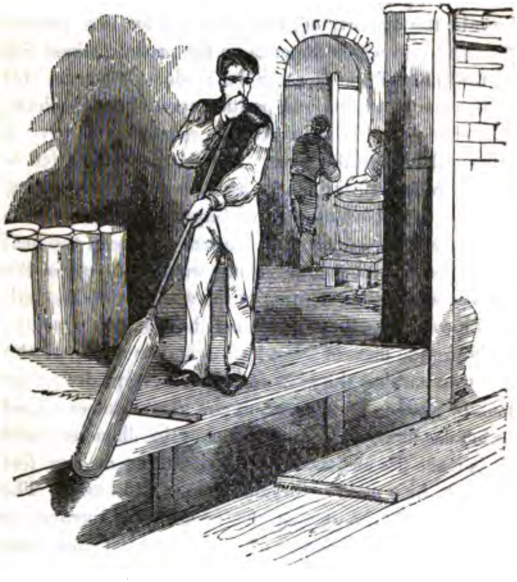
It would be in vain to attempt to enumerate the examinations which the plates undergo. In every stage of the manufacture the experience of the workman is called for, to determine whether any and what imperfections appear, and how they are to be removed; and as, on the one hand, no manufactured article would betray the existence of defects more readily than a large sheet of plate-glass, so, on the other hand, the most sedulous attention is paid to the detection of such defects when they appear in the course of the manufacture. We need hardly wonder at the comparatively high value of plate glass when the risk and skill involved in the manufacture are duly estimated.

The *silvering* of looking-glasses is a distinct occupation, concerning which a few words of explanation may be offered. In the first place, the designation is a misnomer; there being no silver used. A sheet of tin-foil is laid down on a flat stone or slate table, and on this is poured some mercury or quicksilver (whence probably the misappellation). The plate of glass, being first made perfectly clean, is placed on the liquid mercury, in such a manner as to expel all air-bubbles from between the two; and heavy weights are placed on the glass to force out the superabundant mercury from beneath. The whole is allowed to remain in a slighty inclined position for some days; after which it is found, on the removal of the weights, that the mercury has combined with the tin-foil, and that both together have adhered to the glass, forming what is commonly termed the 'silvered' surface, and giving origin to the brilliant reflection which is the object of the process.

We must now glance at the manufacture of

### *Sheet-Glass.*

This is to a by-stander one of the most inexplicable modes of glass-making. How the workman can possibly obtain a rectangular piece of glass in the way he does, is a sore puzzle at the first glance; and even after it has been witnessed several times, our admiration at the dexterity shown is not one whit lessened. In some of its features the mode of proceeding resembles that adopted in respect to crown-glass; but others are wholly different. Sheet-glass can be made larger in size than crown-glass, and is much employed for glazing large prints and drawings; it being in quality and in value a medium between plate-glass and crown-glass.



Blowing Cylinder for Sheet-glass.

We may say of this, as of the former kinds of glass, that sand, alkali, and lime are the three chief ingredients, and that the preparation and melting are brought about in a manner nearly similar. The workman, when the glass is in a proper state of liquidity, gathers on the end of a tube the quantity of glass necessary for one process of making, and which depends on the predetermined size and thickness of the piece to be made. He rests this ductile mass in a horizontal position upon a wooden block, which has a hollow or depression calculated to give a cylindrical form to the mass. A fine stream of water is allowed to flow on the block, as a means of preventing the wood from burning, and of imparting a kind of brilliancy to the glass: the proper balance between the heat of the glass and the coldness of the water being one of the points to which the attention of the workman is directed. The blower raises the other end of the tube to his mouth, and blows the mass of glass into a hollow form, at the same time turning the mass round uninterruptedly in the block of wood. By this means the glass assumes a kind of globular form, eight or ten inches in diameter; and this is made the nucleus of a cylinder three or four feet in length, by a most remarkable train of processes. The workman holds the glass at the mouth of a furnace, to heat it to a certain degree of softness, at the same time keeping it rotating to prevent it from falling off the tube. He then lets the glassy mass hang downwards, and swings it to and fro in a recess or cleft in the floor of the shop; by which movement the globe, yielding to its own weight by the softness and ductility of its substance, elongates into a cylinder with hemispherical ends. Again is the mass heated and rotated, and again is it swung like a pendulum at the end of the tube; until, at length, the workman fairly swings it round in a vertical circle, at the imminent risk (as it seems to a looker-on) of shattering the cylinder into fragments. That the globe will elongate when softened and hung downwards is what may be reasonably expected, and that it will remain hollow during this elongation is also easy to conceive; but that it should become almost a perfectly true cylinder from end to end, that the thickness should be the same in every part, that the diameter should be equable throughout a length of three or four feet, that the cylinder should solidify in this form, and that it should remain all this time attached simply to the end of a tube, are results which few persons could anticipate, and which are even more remarkable as exemplifications of the skill of the workman than the 'flashing' of the circles of crown-glass.

The manner in which the two ends of the cylinder are made open and circular is curious. The workman stops the end of the tube, by which a certain quantity of air is enclosed in the cylinder; and by holding the remote end of the cylinder to the fire, the air within becomes so heated and expanded as to burst for itself a means of exit, by forming a small hole at the end of the cylinder. This hole, by heat and rotation, is expanded to the diameter of the cylinder; and thus one of the closed ends is rendered open. The other end is severed from the tube by first heating and then suddenly cooling a line round the circumference of the cylinder.

The quickness with which all this is done is not the least remarkable feature in the process. A few men soon accumulate around them a large assemblage of these finely formed cylinders (which may at an average be taken at forty inches long by nine or ten in diameter); and these are rested upright on the floor for a temporary period. But then, how to transform these into rectangular plates or sheets? In the first place, each cylinder is laid on its side, and a hot iron wire is drawn along the interior from end to end: the glass gives way at this line, and an opening is effected. Another workman next gradually warms the cylinder, and places it on a flat stone in a heated oven, with the crack or fissure uppermost; and in a short time the glass becomes so softened by the heat as to fall down by its own weight, spreading out into a sheet about thirty inches wide. While in this position the workman introduces into the oven an instrument formed of a piece of charred wood at the end of a handle, and with this he rubs the sheet of glass until it is made as flat as possible at the surface. After this, the sheet is placed up edgewise in an annealing-oven, and there kept to cool gradually.

It is worthy of remark that the workmen employed in this department are mostly foreigners. This kind of glass was made in Germany and France before being known in England; and as the quantity of it made is comparatively small, it does not seem yet to have been undertaken by English workmen, but to be still wrought by foreigners who have acquired the requisite tact and judgment by long practice. At all events, the earnings of the men are high, and there is a remarkable cleanness and neatness in their personal appearance: they have blue and white striped dresses, and contrive to maintain a tidiness both of person and of dress which is not a little commendable.

There is a kind of glass sometimes made, inferior both to crown and to sheet glass, called *broad-glass;* and this is manufactured in a manner somewhat analogous to that just described. But as no new features are involved in it, we may pass on to say a few words respecting the last sort which we enumerated, and which is designated, from its characteristic use, as bottle-glass.

Making Glass Bottles.

### *Bottle-Glass.*

A greater weight of bottle-glass is made every year in England than of all the other kinds put together. Wine and beer bottles, pickle-bottles, oil-bottles, bottles for chemical liquids, &c. are required in such abundant quantity, that four or five hundred millions of pounds weight are made (and we may suppose broken) annually in England.

The materials for glass bottles are coarser and cheaper than for any other kinds of glass. Neither beauty of colour nor freedom from specks is of much moment for these articles, and consequently the alkali and other ingredients employed are the least costly. The mode of working differs from all the former instances so far as this—that the bottle receives its shape mainly from a mould.

In a bottle-glass house there is a kind of central furnace, containing the pots in which the 'metal' is melted; and around this is the vacant place where the men work, together with the moulds and other apparatus for aiding in the production of the bottles.

A workman (the *gatherer*) gathers on the end of a tube as much glass as will make (say) a wine-bottle. This he hands to another workman, the *blower*, who, whilst blowing through the tube, rolls the glass upon a stone, and elongates a portion which is to form the neck of the bottle. He then inserts the bulk of the glass into a brass or cast-iron mould, which gives the exterior form to the bottle; while, by continuing the blowing, he forms the internal cavity. The blower then hands it to the *finisher*, who further fashions the neck by putting on a little ring of glass, then trims the mouth of the bottle and gives shape to the bottom; and, lastly, detaches the bottle from the tube. A boy then lifts up the bottle on a kind of pronged fork, and carries it to the annealing-oven, where it is allowed to cool gradually. This is, in fact, a rougher kind of work belonging to the same general class as the making of flint-phials, noticed in a former page.

This circle of operations is continued with much quickness, four or five men being able to make a hundred wine-bottles in an hour; and, with a few modifications, according to the size, shape, and purpose of the bottles, may be taken as a general exemplification of the mode of proceeding. The vicinity of the Tyne and the Wear is abundantly supplied with many of the requisites for bottle-making; and hence the manufacture is there largely carried on.

## CHAPTER IV.

### CARPET-MANUFACTURE.

Of the carpet-manufacture in this country it has been observed ('Penny Cyclopædia')—"The consumption of carpets in Great Britain up to about the middle of the last century, was so very trifling that, as a manufacture, it was hardly deserving of notice; and although now so essential to our warmth and comfort, a few generations since, a carpet was only partially used in the mansions of the rich. Only a few manufactories, of which that at Wilton was the most important, existed in different parts of the kingdom; and at Kidderminster, which is now the principal seat of the trade, and where at least five thousand persons are employed in its different branches, the carpet-manufacture did not commence before the early part of the eighteenth century. We doubt whether at the commencement of the nineteenth century one-fourth of the present number of carpets was manufactured."

We may here remark in addition, that the vicinity of Glasgow has become an important seat of the carpet-manufacture; there being, in that locality, factories in which the whole circle of operations, from the washing of the dirty fleece to the shearing of the woven carpet, is conducted.

The nomenclature familiarly applied to carpets is—like many other instances of manufacturing phraseology—ill calculated to convey an idea of their distinctive features or of their mode of manufacture. The terms Scotch, Kidderminster, Wilton, Brussels, Turkey, Persian, Venetian, &c. as applied to carpets, no longer strictly indicate the places of manufacture, however applicable they might have been in the first instance. Indeed, there is no little confusion in the matter; for 'Scotch' carpets and 'Kidderminster' carpets are the same: 'Venetian' carpets were never, it has been asserted, made at Venice at all: 'Brussels' carpets are made at Kidderminster; while 'Kidderminster' carpets are not made in that town so extensively as in Scotland. These anomalies apart, however, we will endeavour to give such a sketch as will illustrate the broad features of the manufacture generally; and for this purpose it matters little where we take up our station, provided the manufacturing arrangements are sufficiently complete.

It is necessary here to mention the connection between the spinning and the weaving in carpet-work. It is well known that the spinning and weaving of cotton are not necessarily carried on in one establishment, or by one firm: some being 'spinning-factories,' some 'weaving-factories;' and some both conjoined. The same remark is applicable to the carpet-manufacture, with this modification, that the worsted is rarely spun in the same factory where the carpets are made. At Kilmarnock, at Kidderminster, and other towns where large quantities of worsted are used, there are 'worsted-mills,' the owners of which prepare spun-yarn, and sell it in a spun state to the carpet, shawl, tartan, &c. manufacturers. Occasionally, however, the spinning is conducted in the weaving factory, and we will therefore glance at worsted spinning before noticing the actual manufacture of the carpets.

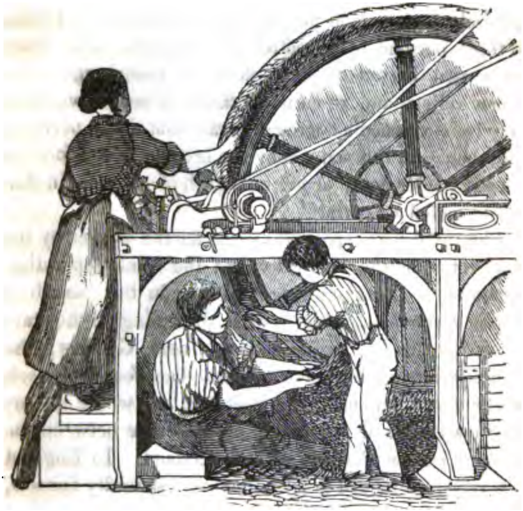
The wool reaches the spinner in two forms; *fleece*-wool and *skin*-wool: the first being that which results from the shearing, and the latter being the wool taken from the animal when killed. The former is the better of the two, but both are employed. The wool comes in bags containing about ten stones each—a 'stone' in this commodity being twenty-four pounds—therefore equal to two hundred and forty pounds weight per bag, technically called a 'pack.' The bags are in the first placed stowed away in a long shed or warehouse; from whence they are transferred to an upper floor, occupied as a sorting-room. Here a number of men stand at benches in front of a range of windows; and the wool, when taken from the bags, is placed on these benches to be sorted. So different is the mode of growth on different parts of the animal's fleece, that as many as ten different qualities of wool are procurable from the same fleece; some best fitted for the warp of the carpet, some for weft, some for coarse work, some for fine, &c.; and it is the office of the sorters to separate the fleece piecemeal into its various qualities.

The wool, thus separated, is next transferred to a lower building, where it is washed, scoured, or cleansed from the grease adherent to it. The washing is a very simple affair, but the 'wringing' or draining is ingeniously effected, thus:—There is a wooden vessel filled with a hot ley of soap, soda, and water, into which the wool is dipped; and after a little stirring, the wool is lifted up by a kind of pitchfork, and held where it can be caught between two rollers, which by great pressure force out the water from the wool, leaving it nearly dry. To complete the drying, the wool is then taken to a hot-room, where an economical use is made of the heat radiating from the boilers of the steam-engine: the drying-room is over the boiler-room, and is thus effectually heated by caloric which would otherwise be wasted. This is only one among many instances which our manufactures exhibit, wherein the possession of a steam-engine yields benefits not originally contemplated when it was erected; such, for example, as a supply of hot water from the condensed steam, the warming of a whole factory by steam, the heating of rooms for drying goods, &c.

The sorted, cleansed, and dried wool then undergoes processes by which its fibres are brought more or less into a parallel position, preparatory to the operation of spinning. In the cotton-manufacture the process of 'carding' is that by which the fibres are laid straight; but in the preparation of wool some kinds require a different mode of procedure, called 'combing.' Supposing the wool to be of that kind or for that purpose which requires carding, the routine proceeds thus:—The wool is first placed near a revolving cylinder, called a 'teazer,' whose external surface is studded with bent hooks; and these hooks, catching hold of the locks of wool, disentangle and open them, separating them fibre from fibre, and preparing them for the 'cards.' These cards are points or wires, much finer than the hooks of the 'teazer,' and disposed around the exterior of a long series of cylinders: the wool is caught from one cylinder to another, twenty or thirty times in succession, whereby all its fibres become arranged very nearly in a parallel layer; and after leaving the last cylinder, it assumes the form of a delicate, tender riband or 'sliver' about two inches in width.

The 'carding-machines' employed in this operation are very large and complex pieces of mechanism; and ten or a dozen of them, arranged side by side, give a very busy appearance to the 'carding-room.' They are almost automatic, requiring very little personal attention.

The 'combing' of the wool is another mode of separating the fibres from their knotted locks. In the preparation of hemp for ropes, and of flax for linen, the fibres are disentangled by means of an instrument called a 'heckle,' consisting of a number of teeth or spikes inserted in a board; and a somewhat similar plan is adopted for wool. The fibres are torn one from another in three different ways, all involving, however, the same general principle of action. In the simplest mode of proceeding, the wires of a kind of large comb are heated, and the comb being fixed with the wires uppermost, the wool is laid on them, and combed out by the teeth of another similar comb. This is the method for the finest wools. That of coarser quality is placed on the surface of a revolving roller, and combed out by passing on and between the points of a kind of heckle. There is, however, another and a larger machine, which acts in a remarkable manner. It consists of two large wheels, six or seven feet in diameter, rotating so that their peripheries may be nearly in contact. The periphery, or circumference, of each wheel is formed by a series of wires or spikes, on and between which the wool is placed: the wires on the one wheel then comb out the wool on the other, and at the same time separate it into two portions—short fibres, called 'noils,' and long fibres, called 'top'—which are afterwards used for different kinds of work. The short fibres are taken from the wheel, in a bunch, by another boy or girl, while a third removes the longer fibres in a continuous but irregular string. The portion of the machine at which the juvenile operatives are engaged is here sketched. Without detailing the particular circumstances under which 'carding' or 'combing' are resorted to, or the respective purposes to which the 'noils' and the 'top' are applied, it will suffice to say that all this is preparatory to the



Combing Worsted for Carpets.

spinning of the yarn: it may, however, be explained that the long 'combed' wool is used principally for Brussels and the finer kinds of carpeting, while 'carded' wool is employed for Scotch or common carpets.

We next transfer our attention to a long shop or room wherein the worsted is 'drawn' and 'roved,' processes precisely analogous in principle, and nearly so in details, to those pursued in the cotton-manufacture. The fibres are passed between rollers, doubled, passed again between rollers, and so on many times in succession, until they have assumed a degree of parallelism almost perfect; and, being in this state, they are brought to the form of a loose tender cord, about an eighth of an inch in diameter, called a 'roving.'

The rovings are spun into yarns for the weaver by the usual action of the 'throstle' and the 'mule' spinning-machines. The spinning-rooms contain the machines whose revolving bobbins reduce the roving to the state of yarn. In the carpet-factories near Glasgow, the spinning-rooms are attended by the bare-footed damsels whose duty it is to mind the machines, and whose appearance marks one of the points of difference between the working classes of England and Scotland. In England it is very rare indeed to see either sex, especially females, without shoes and stockings, except in the very humblest and most depressed classes of the community: the stockings may be full of holes, and the shoes may have scarcely any 'under-leathers' to keep the 'uppers' together; yet, such as they are, we everywhere see them. In Glasgow, however, and in most parts of Scotland, the absence of feet-coverings is by no means an evidence of extreme poverty or slovenliness. When Jeannie Deans took off her shoes and stockings, and carried them in her bundle during part of her journey to London, she only followed a well-understood practice among her countrywomen. In the kitchens of many taverns and respectable houses of Glasgow, at the present day, the female domestics wear neither shoes nor stockings; and out in the open streets, especially in the vicinity of the Broomielaw and of the Salt Market, gold ear-rings and pink bonnets, and silk ribands and shawls, may frequently be seen accompanied by bare ankles. When, therefore, we meet with similar instances in a spinning-mill, we may attribute it not to any peculiarity attending the occupation, but to the custom of the place.

But to return. Some of the spun-yarns are doubled and twisted again, to make strong threads for the warp of the carpet; while others are so prepared as to present more elasticity than strength, for use as weft or cross threads. When, however, the spinning is finally effected, the yarn is carried up to another room or shop provided with a number of hexagonal frames or reels, on to which the yarn is wound, in the same manner as the silk in a silk-mill. Some of these are called '4-quarter reels,' some '8-quarter;' and the yarn, after being removed from them, is wound up into hanks, and the hanks into bundles.

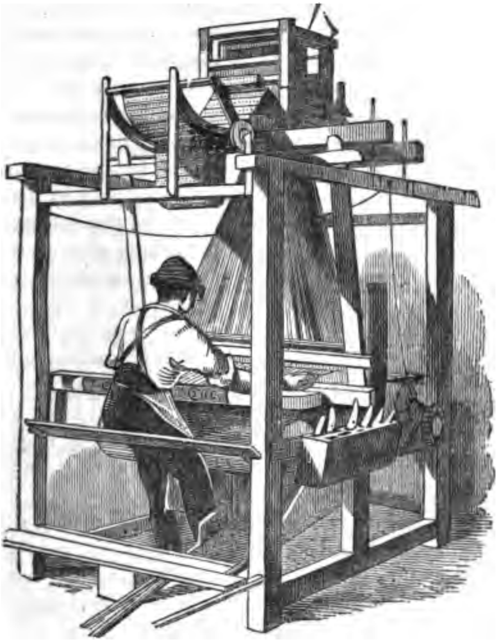
The dye-house is the next place to which we have to direct our attention. All carpet-worsted is dyed while in the state of yarn, sometimes by the carpet manufacturer, but at other times purchased by him in a dyed state. Such dye-houses are provided with the apparatus, mostly of a simple kind, for dyeing the hanks, which are opened so as to allow each individual yarn to be acted on by the dye. The usual mineral and vegetable colours are employed; and the yarn, after being dyed, is hung upon poles to be dried in a heated room.

We now approach that part of the operations in which the spun and dyed yarn is about to be woven into the form of a carpet: the warp threads to be attached to the 'harness' and 'heddles' of the loom, and the weft threads to be wound on the pirn of the shuttle. It must be familiarly known to every one who has ever examined the texture of different kinds of carpets, that very great diversity is exhibited by them; and unless these diversities are borne in mind, the manufacturing arrangements can hardly be understood. Some kinds of carpet exhibit the same pattern and the same material on both sides, the colours only being reversed: another kind exhibits a woollen or worsted surface on one side, and a hard hempen or flaxen surface on the other: another kind presents all the appearance of a velvet surface, exhibiting the peculiar 'pile' or 'nap' which forms the distinguishing characteristic of velvet: another kind presents a richly soft surface half an inch in depth, in which the ends of the fibres, instead of their sides, are exhibited to the eye. It is obvious that very different arrangements of the weaving apparatus must be called for to aid in the production of these different kinds of carpet.

The first which we may notice is the common *Scotch carpeting*, which is woven in lengths about a yard in width, and then sewed together edgewise to form a carpet. This carpeting is formed without the admixture of any flax. The warp is of worsted and the weft is of wool; the difference between the two being that wool has shorter and finer fibres than worsted; and the fabric is so constructed as to constitute a double cloth, having two sets of warp and two of weft, each warp being intersected by both the wefts. It is, in fact, like two pieces of worsted cloth united together, surface to surface, and it might be possible to separate one from the other without destroying the web of either. Kilmarnock, a busy town eastward of Ayr and southward of Greenock, is one of the chief seats of this manufacture. It is stated in the recent 'Topographical Dictionary of Scotland,' that "the carpet manufacture may, amid many conflicting claims, be regarded now as the staple of Kilmarnock. Even twenty or twenty-five years ago it rivalled that of Kidderminster in England, and had no competitor in Scotland; and about that time, or a little later, it was greatly improved by the mechanical inventions of Mr. Thomas Morton, a citizen, who gives name to a locality in the vicinity of the Gas-Works, who taught his townsmen at once to save time and labour, and to achieve accuracy and an extensive variety in their patterns; and who, so early as 1826, received public demonstrations from the manufacturers of the town of the debt of obligation which they felt his genius had imposed. . . . The wages of the carpet and rug weavers run from 12*s.* to 14*s.* per week nett, and occasionally higher. The yearly value of the carpet manufacture was estimated, in 1837, at 150,000*l.* The carpet-factories are six in number." Brussels, Wilton, and Scotch carpets are made in Kilmarnock; but in that town, as well as in Scotland generally, the last-named variety is that which is most extensively made.

The general process of weaving Scotch carpeting is the same everywhere, and may be thus illustrated. The weaving-shops are long rooms, having looms ranged on one or both sides through the whole length. Each weaver has his seat in front of his loom, where he drives the shuttle with one hand, regulates the shuttle-box and the 'batten' or 'lay' with the other, and works the treadles with his feet. No steam-power is employed, nor is an assistant necessary, as in some other kinds of carpet-weaving. The worsted warp-threads are arranged in two tiers, or, if it be a 'three-ply' carpet, in three tiers, by which a triple cloth is produced. Above the warp-threads is a very complicated assemblage of cords, called the 'harness,' the object of which is to draw up certain of the warp-threads for allowing the passage of the weft between them; and as the weaver, even if his feet and fingers were doubled in number, could not manage all these strings in their varied complexity, he is aided by an ingeniously constructed barrel, whose surface is studded like that of a barrel-organ. The studs are arranged on the surface in a certain determinate order, which depends on the pattern to be produced in the carpet; and when the barrel rotates, the studs, acting on several short levers, govern the movements of the warp-threads in a definite system, just as the arrangements of the pins on an organ-barrel act upon the pipes in a certain order according to the time to be played. As one organ-barrel, studded in a certain way, can only lead to the performance of one tune or set of tunes, so one loom-barrel, with a definite order of studs, can only lead to the production of one design in the carpet. The analogy between the two cases is so close, that we willingly make use of one to illustrate the other.

The mode of arranging the pins on the barrel depends altogether on the pattern to be produced, and this pattern is first drawn upon paper. There are designers for carpet-weaving, as well as for calico-printing; the artists in one case as in the other exercising their taste to produce new and elegant designs. From the designs the barrels are studded, and thus made ready for the loom;

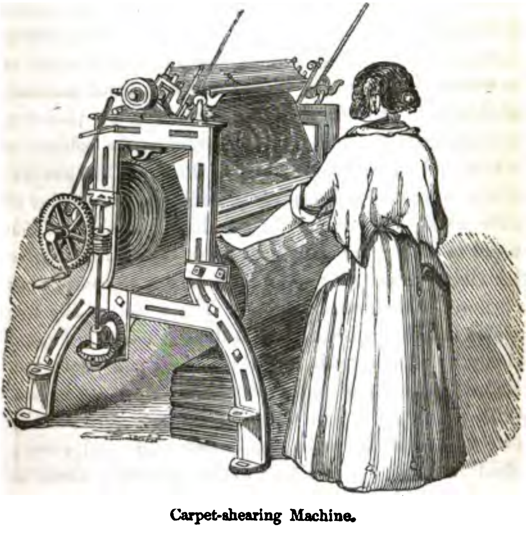


Scotch Carpet Loom.

but every year witnesses the gradual decline of this mode of proceeding; the more efficient 'Jacquard' apparatus being used in its place. How this beautiful contrivance is brought to bear on the movements of the warp-threads we had occasion slightly to notice in the sketch of the bobbin-net manufacture at Nottingham, in the volume relating to Textile Manufactures; and we may now mention that it is extensively used in the carpet manufacture. Sometimes there are as many as six hundred perforated cards for the production of one pattern, and two or three hundred levers or needles acted on by them.

The horizontal warp-threads, with the studded barrel or the Jacquard apparatus over them, form what we may term the permanent furniture of the carpet-weaver's loom; but the arrangement of shuttles is also very curious. There are from two to twenty shuttles for each pattern, the number being great or small according to the number of colours in the pattern. These shuttles are placed in a kind of box at the weaver's right hand, and he takes them out as he wants them. We may suppose that red, blue, and white, for example, alternate in the pattern: in such case he throws a red shoot with one shuttle; lays it down and takes up the blue shuttle, with which he throws a shoot; lays down this again, and takes up the white shuttle; and so on, keeping his hands incessantly employed, for he has not only to change the shuttles in this manner, but also to drive up each thread of weft as it is thrown. The arrangement of the barrel or the Jacquard apparatus is such, that when one colour, or one set of two or three colours, is done with for a time, a little bell is rung, by which the weaver is warned to place those shuttles in the side receptacle, and take others into use, according to the pattern. In the preceding cut is a representation of the general appearance of a Scotch carpet loom.

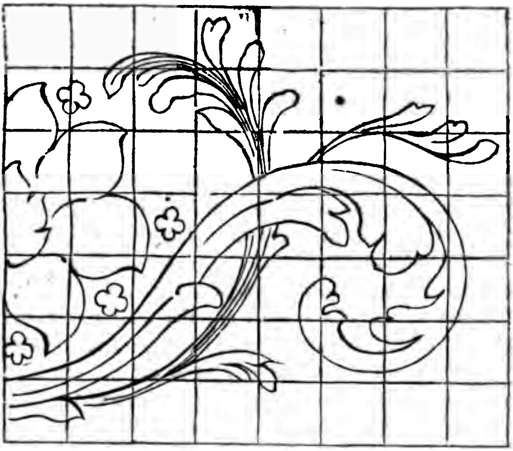
Let us next direct attention to a more expensive and finished carpet than the Scotch, viz., the *Brussels*. A Brussels carpet is composed of linen and worsted, the cloth or textile fabric being formed wholly of linen, and the worsted forming a kind of surface superadded to the fabric thus made. The mode of effecting this is highly curious:—The Brussels carpet-loom exhibits at its hinder end a series of frames, five or more in number, filled with bobbins of yarn; the frames being placed a. such angles as to allow the yarn from all the bobbins to unwind and form a uniform warp of threads. The weaver, sitting in front of the loom, is provided with a number of brass wires, each rather longer than the width of the carpet to be woven; and these wires enable him to give that ribbed or corded appearance which is so conspicuous a feature in Brussels carpeting. There are usually five colours in a Brussels carpet, and these colours are formed wholly by warp-threads, of which there are about two hundred and sixty of each colour in twenty-seven inches' width of carpet. The warp-threads are governed by some such apparatus as in the former case; and when a 'shed' has been opened, the weaver throws a shoot or two of linen thread. He then introduces a wire under some of the coloured warps, and over all the rest; by which a series of loops is formed, which present a round and full appearance when the wire is afterwards withdrawn. He thus proceeds, throwing a shoot or two of weft, then beating them well up, then inserting a wire, then throwing more weft, and so on, repeatedly changing the colour of the uppermost warp-threads by mechanism connected with the treadles. At intervals he takes out all the wires, which have assisted in forming the ribbed-like surface of the carpet. One effect of raising the upper coloured warp in this way is wholly to hide the linen thread. The weaver is assisted by a boy in adjusting the 'shed' for the reception of the weft.



Carpet-shearing Machine.

Taken in all its parts, the Brussels-carpet loom is decidedly a complex piece of mechanism, and requires for its due comprehension a very close attention, even from an eye-witness of its operation. The same apparatus, with a slight alteration, is used for the production of

*Wilton carpets*, which differ from Brussels chiefly in this—that the rib or raised part, instead of remaining whole, as in Brussels carpet, is cut by means of a sharp instrument, so as to form a velvet-like pile. The wires, instead of being smooth at the upper surface, have a groove running along the whole length, which assists the weaver in drawing a very fine knife across the worsted yarns which lie over the wire, and thereby severing them.



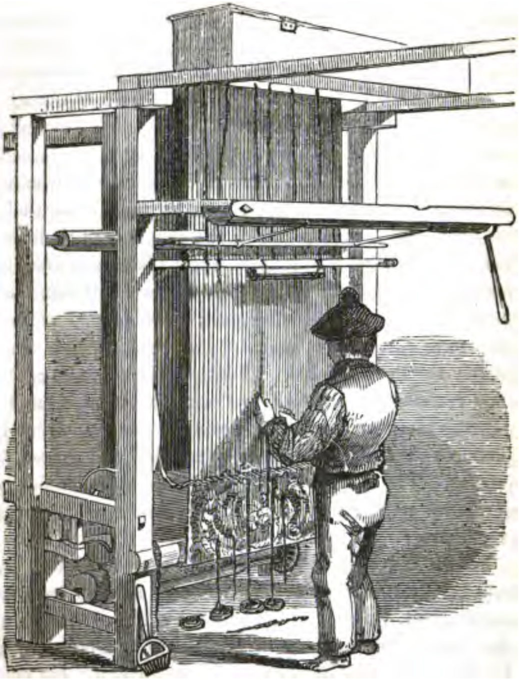
Persian-rug Pattern-paper.

However different the common Venetian or stair-carpeting may appear to be from these finer kinds, yet it resembles them in this—that the warp alone forms the visible upper surface; the weft, which is sometimes woollen, sometimes linen, and sometimes cotton, being thrown in to form the fabric, but without showing at the surface. The warp is generally arranged in stripes of different colours, and sometimes a kind of plaid pattern is produced; but generally the pattern is so plain as to require but little complexity in the weaving apparatus.

Most carpets, after being woven, require to have the surface sheared or cut, for the removal of loose fibres, and for regulating the length of nap in those which constitute pile-carpets. This shearing is effected by a very ingenious machine, in which a screw, whose worm or thread forms a cutting edge, revolves so that this edge shall come in contact with a straight horizontal edge, and thus act like a pair of scissors. The carpet is so adjusted as to be drawn between these two edges, by which the surface is sheared all over; the quantity cut off being dependent on the adjustment of the two cutting edges. The machine is represented on page 108.

*Turkey* or *Persian carpets* are the most costly and luxuriant of all, and are produced in a very remarkable way. They are not extensively made in this country; but there is an article of manufacture known as 'Persian rugs,' which will afford us some idea of the matter. The arrangements for making a Persian rug are these:—The warp is formed of linen-yarn, and is arranged vertically. Just above the level of the weaver's eye is placed a rolled-up paper pattern, on which the device is drawn, and which has crossed lines to represent the warp and weft threads, like the 'Berlin' patterns now so well known. If, in the preceding sketch, we suppose a number of other lines to be introduced between those here given (and which we have omitted, to avoid confusing the figure), it will represent a portion of one such pattern. The weaver is provided with stout worsted yarn of various colours, and twists this yarn round the separate warp-threads, twining it round two threads, and then cutting it off so as to leave two loose ends, say half an inch long each. He has scissors in his right hand, with which he cuts the worsted. He looks up at his pattern repeatedly, to see what coloured worsted is to occupy a particular spot, and to use the corresponding coloured thread. When he has knotted in a row of little tufts of worsted across the whole width of the web, he takes a shuttle in his hand, and throws in one or two shoots of stout linen-yarn, which keep the tufts in their places and assist in forming a firm fabric. The ends of each tuft stand out prominently, and by a subsequent dressing and cutting they form such a level and full surface as to hide completely the linen threads. This is throughout one of the most remarkable modes of producing a carpet, from its extreme simplicity, and the beautiful material which it produces; but it is necessarily a very slow and expensive process. The loom is wholly free from the complexity of 'barrel' and 'Jacquard' apparatus, and boys can work it effectively.

Before quitting the subject of carpet-making, we may briefly allude to a very singular kind of mosaic-work carpet, which was described by Mr. Vignolles at the Manchester meeting of the British Association, in 1842. He did not state who was the inventor, but confined himself to a general exposition of the principle involved. The carpet is composed of innumerable transverse sections of variously coloured woollen threads, about one-eighth of an inch long each, and standing vertically; one end being seen, and the other connected by India-rubber to a piece of cloth. The working machinery was described as consisting of two frames of fine wire, or perforated zinc, with as many as four



Persian-rug making.

thousand perforations in a square inch, placed over each other, at a distance of five or more feet, according to the height of the room: the two wire frames are horizontal, with the meshes of the one exactly over those of the other. The design to be copied being then traced on the top side of the upper frame, a workman passes threads of dyed wool through the corresponding holes in the top and bottom frames, varying his colours and shades to imitate those of the design. To judge of the effect, he looks down on the upper ends of the threads, where each colour occupies a certain definite position and arrangement. When all the threads are thus introduced, they form a compact vertical mass, presenting no semblance of a picture or design when viewed sideways or horizontally. When the threads have been thus introduced in their proper order, the upper ends are covered with India-rubber cement, and a cloth is laid upon them, also covered with cement, by which the ends of the threads are made to adhere firmly to the cloth. By means of a sharp cutting instrument, the entire mass of threads is now cut through transversely at a distance of about one-eighth of an inch from the cloth. This process being repeated, a fresh copy is obtained from every eighth of an inch. In a frame of which the upper and lower surfaces are five feet apart, four hundred and eighty copies can thus be cut from one mass of threads; and this number could be increased by an increased height of the frame. The multiplication of copies here alluded to seems to be one of the features for which the method is noticeable; since the expense of a single copy, if only one could be produced by one threading of the wires, would be too great to answer as a commercial speculation.

As the use of tapestried hangings for the walls of rooms is nearly obsolete, the method is proposed to be applied to the formation of carpets, rugs, curtains, chair-covers, table-covers, &c.; for some of which purposes the nap or pile might be left longer than one-eighth of an inch, thus producing a thicker and softer substance.

# CHAPTER V.

## FLOOR-CLOTH MANUFACTURE.

The material with which this manufacture is concerned, has reference, like the one just noticed, to a covering for floors, and has certain points of resemblance with it in two respects; the designing of a pattern from which the workman may operate; and the weaving of the main substance of the material itself. Beyond this point, however, much diversity of operation is observable.

What would our ancestors have thought, if they could have seen the varied and glittering devices which now deck the floors of our apartments? In the times when tapestried hangings decorated the walls, the floors were either left bare or were covered with green rushes renewed from time to time as occasion required. Our old annalists and county topographers make repeated allusions to the preparations of the 'Great Hall'—a component part of most old mansions—on the occurrence of festivities, by the spreading of clean new rushes on the floor. At what period this custom was discontinued it would perhaps be difficult to say. The great beauty of the joinery-work in the floors of the majority of old mansions seems to point to the fact that they were intended to be left bare; and the polished boards, frequently arranged in a skilfully-contrived mosaic pattern, still remain to attest the care taken in their preservation. The first woven fabric used as a floor-covering in England was probably some coarse kind of drugget, for it seems at least consistent to suppose that the costly carpets imported from Turkey were not introduced until rough attempts had been made to produce a home-manufactured fabric. But be this as it may, the general use of carpets in England, as was observed in the last chapter, extended itself very slowly.

Still more recent was the introduction of that kind of floor-covering which is made of *painted canvas*, and which is generally termed *oil-cloth* or *floor-cloth*,—though *painted-cloth* would perhaps be a better name. The steps whereby we may suppose this material to have been gradually brought to the state usually presented by it at the present day are simple and obvious. In the first place a coarse hempen or flaxen fabric was woven and laid down as a floor-covering. It was then probably suggested that the durability of the material would be greatly increased by laying on a coating of paint, or by saturating the fibres of the cloth with oil or paint, allowed to become thoroughly dried and hardened before the cloth was brought into use. The painter would then exercise his taste in producing a *pattern* on the cloth, by using paint of different colours, and applying his brush with reference to some particular device. Then would ensue the use of *stencil-plates*, as a means of producing an unlimited number of copies of the same pattern, so as to expedite and facilitate the painting of the device. The stencil-plates were probably made of thin sheet-metal with the pattern cut or stamped out of them; a pattern could be produced by painting the canvas—previously prepared with a ground-colour all over—in the parts left bare by the stencil-plates; the pattern, too, would be more or less elaborate according as there were or were not different colours, one stencil-plate devoted to each colour. Lastly ensued that improvement which arises from printing the device by blocks, the face of which are cut similar to the blocks in wood-engraving; a method which admits of very much closer accuracy and neatness than can be attained by the use of stencil-plates.

That these successive stages in the progress of the manufacture are not wholly suppositive may be shown by a kind of historical memento of the manufacture, still in existence. There is still to be seen the first block ever cut for printing floor-cloth; it is still in the hands of the family of the manufacturer who cut it and printed from it, and remains to show the time—about ninety years—which has elapsed since the use of such blocks originally commenced. Before that time the floor-cloth manufactured, very limited in extent, as may be well supposed, received whatever pattern was intended for it by the use of stencil-plates.

Simple as may appear at first thought to be the mere painting of a piece of cloth, the manufacture of floor-cloth involves many curious processes, which are not ill-deserving of attention. All floor-cloth factories are required to be both lofty and extensive in area; because, as we shall see farther on, very large pieces of canvas have to be extended at different times both vertically and horizontally. In one of the large London establishments, the various parts of the building extend to a distance of about two hundred and fifty feet in one direction; comprising first a show-room, lined on either side with specimens of the finished manufacture, mostly in the form of rolls; then a 'drying-room,' about one hundred and twenty feet in length, by sixty or seventy in width, and of considerable height, in which are suspended finished floor-cloths, which are hung here to dry gradually after the painting has been finally effected; these are placed over poles near the roof of the building, and descend to within a few feet of the ground. The floor of the room is occupied by chalk-marks delineating the size or pattern of required pieces of cloth; or by men cutting a large finished piece of cloth to the required size; or by others opening a bale of canvas, and spreading it out on the floor preparatory to placing it on a roller; or by others hauling up a roll of canvas to the painting-room:—one or more of these operations being carried on at a time according to circumstances. Near the drying-room is the 'colour-room,' wherein all the colours used for painting the cloth are prepared. In the centre of this room is a large horizontal cog-wheel, moved by horse-power; and around it are various machines set in motion by cog-wheels acting in the larger wheel, and employed in the grinding and preparation of the colours.

Other rooms are occupied as store-rooms. One of these is the canvas-room, where the canvas, brought from Scotland in bales, and afterwards rolled up into coils, is deposited till required for use; these coils, about five or six feet high, are ranged vertically on all sides of the room. Another is the 'print-room,' or store-room, where are kept the greater part of the carved blocks used in producing the patterns on floor-cloth: these, as will be easily conceived when we come to describe the process, are necessarily very numerous; in fact, they amount to some thousands, and all are preserved with great care, since the fracture of any of the small projecting points would at once spoil the pattern. The room in which they are kept maintains a pretty constant temperature throughout the year; and the wood of which the blocks are formed thus avoids the injury which might result from change of temperature and moisture.

Another room is the frame-room, a part of the premises so closely filled, that it is difficult at first for a stranger to see what is going forward. He soon observes, however, that the room, which is long, wide, and high, is occupied by a series of vertical frames, with canvas stretched over them, and a sufficient interval between them to allow a man to pass. Let the reader conceive a stretched canvas, about sixty feet long and twenty-four high, enclosed in a frame similar to a schoolboy's slate; and twenty or thirty of these lying parallel, with a slender scaffolding built up in each of the intervals between them; he will then have an idea of the appearance of the 'frame-room.' The greater part of these frames are about the size here mentioned; but there are others extending as much as ninety-eight feet in length, although the height is somewhat less than that of the shorter frames.

Another room is the 'printing-room,' where the floorcloth receives the pattern by which it is distinguished. Here we see square cushions—something like the inking-cushions used in hand-printing—covered with bright colours, and men transferring the colours therefrom by means of blocks to the painted canvas, the latter being stretched out on a long flat bench. And other rooms are similarly occupied by men 'printing' the narrow floor-cloths for passages.

The routine of processes carried on in the manufacture is somewhat as follows:—Opening the bales of canvas; coiling the canvas on rollers; hauling the rollers up to the frame-room; stretching the canvas on the frames; painting the canvas while in this position; removing the painted canvas to the 'printing-room;' painting or printing the device on it; and finally suspending it in the drying-room till ready to be employed as floor-covering. To these successive steps, then, we shall direct our attention.

If we look at the edge of a piece of floor-cloth which has been rent or worn into holes, we shall see that its foundation is a woven fabric of a coarse but stout quality. Some of the finer and superior floor-cloths are coated so completely on both sides with paint, and brought to such an excellent surface, that they assume much more the appearance of leather than of cloth; but still it is easy to satisfy ourselves of the foundation being woven vegetable fibre. Sometimes, when an old carpet of good quality has lost its beauty of appearance without falling to pieces, it is converted into floor-cloth, by having the *back* of the carpet painted and printed so as to form the *face* of the floor-cloth. But this is an exception to a general rule, and we may confine ourselves to the notice of new canvas woven expressly for the floor-cloth manufacture.

We believe that there is one, and only one, establishment in London where the canvas is woven by the floor-cloth manufacturer. The general rule is to have the canvas woven in Scotland, by parties who either confine themselves wholly to this line of business, or at least give it a marked degree of attention. That this is a business very distinct from that of ordinary weaving may be conceived from the fact that the ordinary widths are eighteen, twenty-one, and twenty-four feet. The canvas is brought partly from Kirkaldy, but principally from Dundee, a town celebrated more than any other in Britain for the extent of its manufacture of coarse sheetings, sackings, sail-cloth, and similar woven fabrics of flax and hemp. The looms for the weaving of floor-canvas are made expressly for that purpose, since all the modern floor-cloths are made without a seam. As the weft or width of the cloth extends to six or eight yards, of course the shuttle has to be driven this distance at each successive traverse of the weft-thread. At first sight these cloths have more the appearance of hemp than of flax, but hemp is used only to a limited extent, because it is found not to receive and retain the colour so well as flax; the latter is therefore the material generally employed. The canvas has a fineness of about sixteen or eighteen threads to the inch, and a degree of stoutness which may be expressed by saying that a square yard weighs about twenty-one ounces.

The canvas, after being shipped from Dundee by steam, arrives at the floor-cloth factories in London or elsewhere, in the form of compact bales, about three feet in length, and between two and three in width and depth. Each bale contains canvas of one particular width, the lengths and widths being regulated thus:—one kind measures a hundred yards in length by six in width, another a hundred and eight yards in length by seven in width, and another a hundred and thirteen yards by eight. The bales usually weigh about five hundredweight each. The first operation after they are brought to the factory is to open them, and cut them to such lengths as suit the dimensions of the frames, which, as we have before stated, are between sixty and a hundred feet in length. The canvas is rolled up and deposited in the canvas store-room till wanted.

When a piece of canvas is about to be painted, it might be supposed by one whose thoughts were then first directed to the matter, that it might be laid flat on the ground, pulled and perhaps nailed at the edges to stretch it smooth, then painted, and, when dry, painted on the other side. It will be seen, however, that a very different plan is adopted in practice. A party of men unroll the canvas, and lay it down pretty evenly on the floor of the drying-room. They then take a wooden roller, rather longer than the width of the canvas, and about five inches in diameter, and lay it down on one end of the canvas. On this roller the whole of the canvas is coiled, and in that state can be easily carried from place to place. The roller, with the canvas wound on it, is then erected on one end and hauled up into the frame-room by means of a pulley. Here an iron point or gudgeon is dropped into a hole in a moveable carriage, and the roller is moved to its place in a very simple but ingenious manner. Two or more men hold the upper end of the roller; while others, standing on the floor of the room twenty or twenty-four feet lower than the former, guide the carriage in which the lower end of the roller rests. The roller is thus brought to its proper position coincident with one end of the frame to which the canvas is to be attached. This frame, like all the others, is formed of stout oaken beams, two horizontal, to form the top and bottom, and two vertical, to form the sides or ends. The roller being about the same height as the frame, and a small portion of the canvas being unrolled, it is easy to nail the edge of the canvas to one of the upright posts, thus forming the first part of the stretching of the canvas. The wheel-carriage on which the roller rests is then wheeled onward, the canvas unrolling as it proceeds, parallel with the frame. As it unrolls, the canvas is fastened temporarily to the top beam by means of a simple but ingenious contrivance called a 'quickset'—a much more intelligible name than is often applied to working tools. This quickset is a kind of a screw and nut, provided with a large hook at the top, and a small pointed hook at the bottom: the large hook catches hold of a rod lying on the top of the frame, while the small lower hook catches in the canvas: there is a nut by which the screw is carried up tightly to the upper beam of the frame, so as to keep the canvas nearly at its proper height; while the upper hook, by being able to move along the rod, suffers the quickset to move to the right or left as the canvas becomes stretched. This is only a temporary contrivance, used while the immense area of canvas is being adjusted to the four sides of the frame; but it is one of those ingenious adaptations which could only result from a steady observance of the object in view.

When the low-wheeled carriage, in which the roller rests, has travelled from end to end of the frame, and the canvas has become wholly unrolled, and the upper edge temporarily held up by a number of 'quicksets,' the roller is wholly removed, and the second or remaining upright edge of the canvas is nailed to the other upright beam of the frame. It will readily be understood that, if this beam were a fixture, it would be next to impossible to nail the canvas to it with sufficient tightness and stretch in every part. The beam is loose, and the edge of the canvas is nailed to it while the canvas itself is very loose. Two screws are then brought into use, one attached to the upper end and the other to the lower end of the beam; and each screw being worked, the post is drawn forward until the canvas is fully stretched; after which the beam is fixed, and the canvas remains stretched. When it is considered that each of these pieces of canvas contains from fourteen to eighteen hundred square feet, and that it is drawn out nearly as tight as a drum before operations are commenced upon it, it will be readily supposed that a powerful force is required to effect the requisite strain. When the two vertical edges are properly secured, the upper and lower horizontal edges are fastened. The upper edge is nailed at distances of between two and three inches; and the 'quicksets' are removed when their aid is no longer required. The fastening of the lower horizontal edges requires a force analogous in kind (though not so great in amount) as that applied to the vertical edge. The edge is nailed to the lower beam, and the beam is forced down by means of levers, chains, and hooks, until the canvas is stretched as tightly in the vertical as in the horizontal direction; and in this position it remains for several weeks, while the greater part of the processes are being wrought.

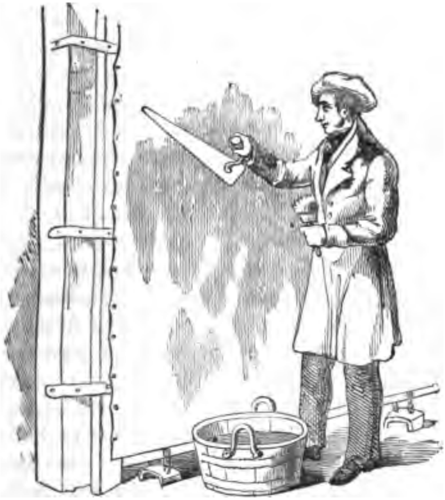
This stretching or 'framing,' then, it will be seen, is a much more important part of the operations than a first thought would lead us to suppose. The canvas is to be painted on both sides; and the mode of framing just described enables each surface to be brought equally into a vertical position. The distance between the frames is probably about thirty inches; and in this narrow space is built up a scaffolding so slender that one almost wonders how it can maintain stability. It is a scaffolding of four tiers in height, to enable the workmen to reach every part of a surface twenty-four feet high. It is necessarily detached from the canvas on either side, and consists in fact merely of a nine-inch board, supported at intervals of every few feet by vertical posts. Access to the upper tiers is gained either by ladders quite upright, or by ledges placed on the upright beams at the end of the scaffolding—a contrivance intended to save as much room as possible between the frames.

If we take up a piece of floor-cloth we shall see that the back is painted as well as the face, although no pattern is imprinted upon it: this is done to increase the durability, the cleanliness, and the appearance of the canvas; but the quantity of paint laid on the back is of course much less than that applied to the face of the cloth. The first operation is to level the surface of the canvas, and to prepare it for the reception of the paint. This is done to the back first, and in the following manner. A weak solution of *size* is prepared, and laid on the canvas with a brush; and while thus wet the canvas is rubbed well with a flat piece of pumice-stone, to level the slight irregularities which occur in the fibrous material. The liquid size not only facilitates this process, but by its gelatinous quality prevents the oil of the subsequently applied paint from penetrating too far into the substance. It is found that the size makes a good foundation or hold for the paint; but it is also found that if the oil penetrates through the canvas, the floor-cloth will become brittle, and not sufficiently pliable; and to prevent this is one of the objects of the size-priming. The pumice-stone—a lava from Vesuvius or Etna—is cut by hatchets into brick-shaped pieces about six inches in length by two in thickness. The workmen rub to and fro with these pieces of pumice over the wet canvas, until the surface is rendered considerably smoother than in its natural state. They mount the highest stage of the scaffold, and rub down the upper portion of the canvas first: then they descend to the next stage, proceeding from end to end of the piece of canvas sixty or a hundred feet in length; and so on to the lower stages.

While the sized canvas is drying, we will visit the colour-room, and briefly consider the nature of the paint applied to the canvas. The painting of floor-cloth is, in principle, analogous to house-painting, though different in some of the practical details. The materials employed are the usual dry, earthy, and crystalline colours; such as white lead, the ochres, the chromes, verditer, Prussian blue, vermillion, &c. These are mostly brought to the factory in tubs or small casks, and are prepared for use in the colour-room. The large earthy colours are ground to powder by means of a crushing-roller three or four feet in diameter by about one thick: this is worked by a horse: and as the shaft belonging to the roller has at the top a large horizontal cog-wheel by which other machines are worked, the whole, or any part of them, are set in operation at one time. When the pigment has been brought to the proper state of fineness by this or any other means, it is put into a tall open vessel called a 'mixing tub,' in which a stirrer is kept rotating by a shaft placed in connection with the large cog-wheel. Linseed-oil, flowing through pipes from adjacent cisterns, is introduced into the mixing-tub; and the stirrer works the ingredients well up together until completely amalgamated. But this mixing would not be sufficient to bring the paint into a proper state for use, since the dry ingredient, although fine, was by no means an impalpable powder. The paint is therefore allowed to flow from the mixing-tub into a vessel beneath; and is thence laded into the hopper or orifice of a pair of millstones precisely analogous to those by which corn is ground. As the paint flows down into the shallow vacant space between the millstones, it becomes ground by the rotation of the upper stone, or 'runner,' and when perfectly smooth and homogeneous, is allowed to ooze out from between the 'runner' and the 'bed-stone' into a vessel beneath. The runner is loaded or not according to the fineness of the paint to be produced. From the vessels into which the paint flows it is conveyed into store-tubs, where it is kept until wanted for use; it is then drawn off into the paint-pans or pots, from which it is used. For some of the finer kinds of colours, or where the quantity required is not such as to render the use of the millstones necessary, a flat stone and hand-muller are employed in the grinding of the paint, such as are commonly used by house-painters; but the principle is just the same.

The paint employed for floor-cloth has these two peculiarities, when compared with that used in house-painting;—it is very much stiffer or thicker, and has scarcely any turpentine in its composition. Both of these characters are given to it to ensure the durability of the cloth; since a large body of paint can be laid on when the consistency is thick, and the paint becomes harder and more durable when the liquid employed is wholly or almost wholly oil, although a much longer time elapses before the paint becomes thoroughly dried and fit for use.

When the paint is prepared, with a thickness or consistence not much less than that of treacle, it is applied to the cloth in a very curious manner, more analogous to the manipulations of a plasterer than those of a painter. The workman holds in his left hand a stout thick brush, which he dips into the paint-pot, and then dabs or splashes on the canvas; the paint is too thick to be brushed over in the usual way, and is therefore laid on abundantly in a few detached patches. The workman holds in his right hand a kind of trowel, consisting of a long narrow blade, about a foot in length, decreasing in width towards one end, and having at the other a handle which bends back over the blade. With this trowel, as represented in the annexed cut, the workman draws the paint over the canvas, smoothing it repeatedly, and drawing a supply from the patches or masses of paint which had been thrown on by the brush. The trowel is worked with its plane or face not precisely parallel with the surface of the canvas, but somewhat inclined, so as to rub or scrape the paint into the fibres of the canvas. The scaffolding, being erected somewhat on the principle of that used by builders, has its successive stages so far distant as to allow the arm of the workman to reach over the intervals between them; so that by descending from one stage to another, and working on the portions of canvas intervening between them, the whole piece can be prepared in a similar way. The edge of the plank or platform forming each stage of the scaffolding is about a foot or fifteen inches distant from the canvas, so that the workman is enabled conveniently to reach it.



Trowel-painting.

The process here described relates to the *back* of the canvas, that surface which is to be underneath or next to the floor when the finished floor-cloth is in use. After this trowel-colour is, however, laid on the back of the canvas, and when it is nearly dry, operations commence on the face, which has hitherto been left untouched. The surface is wetted with a weak solution of size, and rubbed down with flat pieces of pumice-stone, as in the former case, and with the same view of preparing the fibres of the canvas for the reception of the paint. When this is done, the face is not further proceeded with until the back is finished.

The thickness of the colour laid on, and the absence of turpentine or 'driers' in the paint, renders the drying a slow process, from ten days to a fortnight being required for the drying of the 'trowel-colour;' when this is, however, effected, a second coating of paint is laid on, having the same colour as the former, but differing from it in two respects: it is much more liquid, on account of the addition of an extra portion of oil, although considerably thicker than common house-paint; and it is laid on wholly with a brush, instead of being worked conjointly with a brush and a trowel. Hence it is called the 'brush-colour,' to distinguish it from the first or 'trowel-colour.' The tint is of no particular importance; but we believe that each manufacturing firm is accustomed to adopt one particular colour for the back of their floor-cloth, which thus becomes a kind of symbol; besides which, certain private marks are stamped on the back of the cloth, after which that surface is finished. The time has been when a duty was laid on floor-cloth, and when the Excise officer exercised that supervision which is so vexatious and mischievous in manufactures; but this is no longer the case.

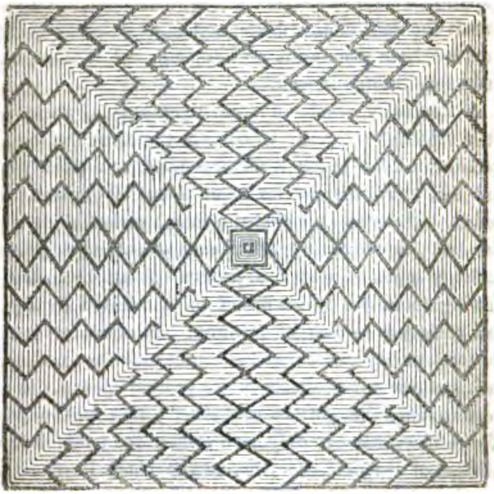
The back of the canvas is entirely finished before the face has undergone any process except the sizing and rubbing down with pumice-stone; but now the preparation of this surface is attended to. A 'trowel-colour,' similar in consistence to that used on the back, is applied and allowed to remain untouched till dry. Then the face is pumiced a second time, to work down some of the asperities and projections which still remain on the surface. To this succeeds a second trowel-colour, in every respect resembling the first; and after a due interval for drying, the surface is a third time rubbed down with pumice. Again is the routine repeated, by applying a third trowel-colour, and following it up with a fourth rubbing-down with a pumice, after which is given a 'brush-colour:' the object of this careful and long-continued series of operations, which occupies a period of two or three months, is to bring the surface of the canvas to a state of great smoothness and pliability. The repeated rubbing with pumice-stone not only levels irregularities, but imparts to the canvas much of the pliability and durability of leather. Where floor-cloths are made expressly to be sold at a low price, the routine of processes is more expeditious and less complete than here indicated.

We now approach that class of operations which, so far as appearance is concerned, is the most important of any, and the most interesting to a stranger who visits a factory of this kind: we mean the *printing*, or transfer of a device to the surface of the cloth. It must be borne in mind that the canvas is all this time in a vertical position, stretched over the frame to which it had been fixed two or three months before; and that the colour of the final coating of paint is that which is to form the ground or foundation colour of the pattern. The printing is effected while the canvas is lying horizontally on a long bench or table, and an entire removal is therefore necessary. The painted canvas is gradually loosened from the nails by which it is fastened to the frame, and is transferred to a roller whose length nearly corresponds with the width of the canvas. The canvas in its original state weighs not much less than two hundred pounds; and the vast body of paint subsequently applied to it increases the weight very considerably; so that the loosening of the canvas from the frame, the transference to a roller, and the hauling up of the roller with its load to the printing-room up stairs, are arrangements requiring some tact and judgment. When the roller is carried up, it is placed horizontally at a few inches from the floor, in front of a very long work-bench; and two gudgeons or projecting axles at the ends of the roller being placed in sockets, the canvas can be uncovered from the roller by the rotation of the latter, and spread out upon the bench to be printed.

Here it will be desirable to offer a few brief explanations respecting the patterns of floor-cloths and the modes of producing them. We have before alluded to the original block first cut for the floor-cloth manufacture. This is now in the possession of a London firm, the successors of the manufacturer who first printed floor-cloth. This manufacturer, Mr. Nathan Smith, was accustomed to manufacture floor-cloth in pieces of two or three yards square, in the only method known at that time (about ninety years ago). Holes were cut in some determinate pattern in thin plates of metal or pasteboard; and these plates being laid on the canvas, and paint applied with a brush, the paint could only reach the canvas at those parts which were not covered by the plate: this is the method of 'stencil-painting,' which is occasionally applied to painting the walls of rooms in distemper, and for other purposes. Each small square of floor-cloth had a border given to it all round; and if a large room were to be covered, several such pieces had to be used. To what extent the floor-cloth manufacture was carried on at that time we have no means of knowing, but it must have been very limited indeed.

A necessary result of stencil-painting is, that very little *substance* of paint is laid on the canvas, since the application of a brush levels the paint to a mere film; and Mr. Smith sought for some means of obviating the defect. He conceived that if a thick wooden block were prepared, the surface levelled and smoothed, a pattern sketched upon it, and this pattern cut out by means of carving tools, the device might be transferred by a process analogous to that of printing. Most readers are at the present day aware that the blocks used for wood-cuts, such as those which illustrate the present volume, are cut so as to leave the pattern untouched; that is, the parts of the block cut are only such as give the *white* lines or portions of the devices; whereas the *black* lines, which usually constitute the picture, are produced from the surface of the block left uncut. The block being pressed down on an elastic surface covered with ink, or ink being applied by means of soft elastic balls, or by means of cylindrical rollers, the surface only of the device receives a coating of ink, leaving the interstices free; and upon this being transferred to paper, the black lines of the wood-engraving result.

On this principle did Mr. Smith conceive that the paint might be applied to floor-cloth, the paint in this case being a representative of the ink in the former. He cut with his own hands a device on a square block of wood measuring about twelve or fifteen inches each way, a device which is represented in the annexed cut taken from the block itself. The pattern, it will be seen, is not a very elaborate one; but still it was one calculated to test the practicability of the plan which had suggested itself to his mind. An impression from this block was exhibited by Professor Brande, in an illustrated lecture on the floor-cloth manufacture at the Royal Institution, about five or six years ago; and the block itself is carefully preserved by the descendants of Mr. Smith, as an historical memento of an important step in the progress



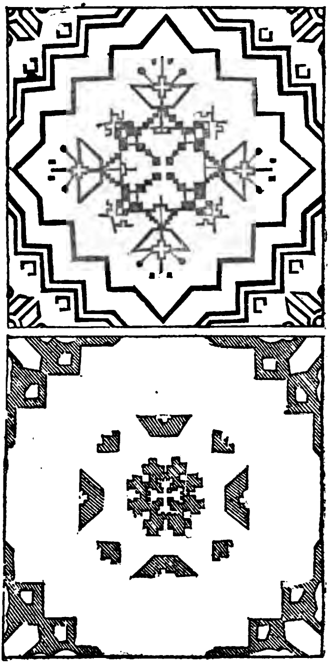
The original Floor-cloth printing-pattern.

of the manufacture. Mr. Smith, like inventors generally, was very careful of his production, and for a considerable period printed all his floor-cloths with his own hand, allowing none of the workmen to see the block, and adopting singular precautions to damp the curiosity of visitors.

The method of printing, originally planned, was very much more simple than that now adopted, owing to a circumstance which it is important that we should clearly explain. If, instead of printing in *one* colour, we adopt *several*, the complexity is greatly increased; for it would be impossible to paint one part of the block with one colour, and one with another, and then transfer the device to the canvas. It is necessary to have as many blocks as there are colours; and the great difficulty consists in adjusting these blocks so as to unite in producing one pattern. The principle is analogous to that of 'colour-printing,' introduced within a few years, wherein, instead of printing with black or blue or any other single-coloured ink, we have several colours combining to produce one pattern. In such a case a series of plates is prepared, either by cutting away those parts which are not to form the pattern, or inserting slips of copper to form the pattern; each plate being made to furnish one particular portion of the device, viz., that of one particular colour. So it is with floor-cloth printing, under a different modification to suit the object in view.

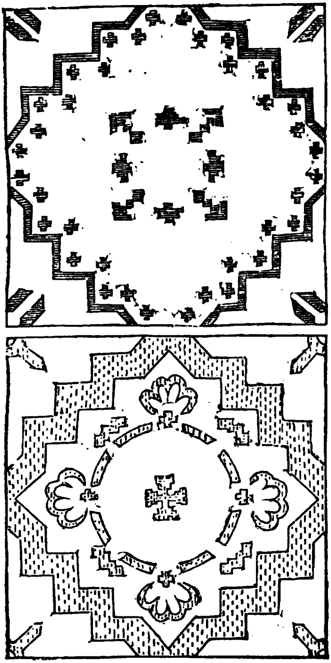
A moment's consideration will show that the carving of the blocks must be a point of great nicety; for if a portion of the device, cut on one block, occurs at the same point as a portion on another block, the two colours will be confounded together, and the device lost. All the blocks are precisely the same size (about fifteen inches square), all are rectangular, and all are applied successively to every part of the floor-cloth, in patches corresponding with the size of the blocks. Each block is cut away at those parts which are left prominent in all the other blocks; so that it will not impart colour to the cloth where the latter would be coloured by any of the remaining blocks. Perhaps we cannot better illustrate this than by taking an actual spemen of floor-cloth, printed in five colours, and showing the precise device cut upon each of the five blocks, as far as we can do so on a small scale. In this

Black.



Green.

Blocks to produce one Pattern.



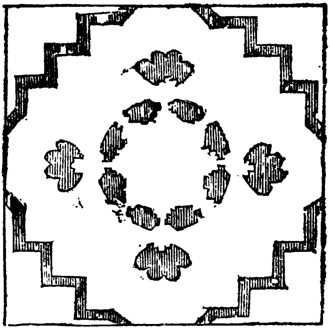
Blue.

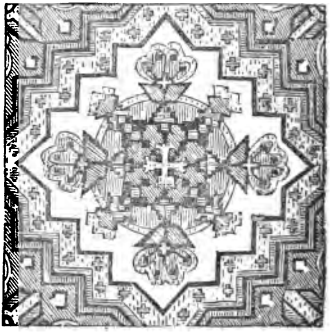
Yellow.

Blocks to produce one Pattern.

group of patterns the colours are represented heraldically, the only way of so doing when black ink only is used; by heraldically is meant the adoption of certain modes of engraving used in printed plates relating to heraldry, such as the following:—white is represented by a white space, black by a black space, yellow by dots, green by oblique parallel lines, red by vertical lines, blue by horizontal lines, &c. One of the six figures represents the finished pattern, built up as it were of five separate portions; and the others show how the blocks are separately fitted to join in producing the design. Of these five, one is yellow, and the dotted portion shows the parts which are left prominent in the block, all the rest being cut away. In another we see, by the arrangement of oblique lines, the pattern intended to be given in a green colour. The red and the blue are in like manner represented by their peculiar lines; and the black portion of the pattern is given in the form which engravers call 'solid.' It will be seen that the device differs greatly in the several blocks; so much so that they could hardly be recognised as uniting to form one pattern, unless that pattern were presented at the same time. In some rare cases as many as ten or twelve colours have been used in one floor-cloth; and

Red.





Combined Colours.

Blocks to produce one Pattern.

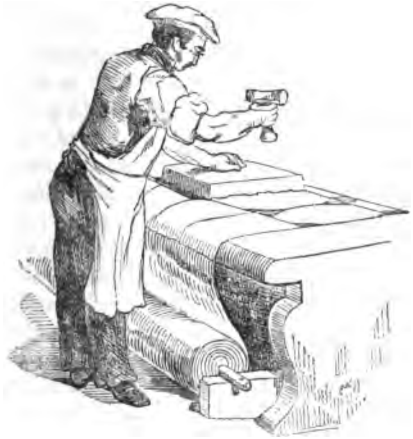
this entails—not only the cutting of an equal number of blocks—but a greatly increased amount of care in every part of the operations.

The choice of patterns for floor-cloth is of course, like that of calico-printing, a matter of taste. Each manufacturer exercises his ingenuity, or avails himself of the ingenuity of others, in devising new patterns. Sometimes, when a piece of ancient tessellated pavement is discovered, such as occurred three or four years ago in the City, the mosaic pattern is immediately copied, and introduced, either as a whole or in part, as a pattern for floor-cloth. But from whatever source the pattern is derived, the mode of transferring it to the several blocks is nearly as follows. The pattern is first drawn and painted in a complete and careful manner, on a sheet of stiff paper exactly the size of the blocks, every colour and every portion of the device being given precisely as it is to appear in the finished floor-cloth. Another piece of paper is then taken, and laid under the first, and by means of a pin or pricker one portion of the device is transferred in outline to the lower paper. Thus: suppose we commence with green; the workman follows the outline of the green portion of the device, pricking through both papers with a pin, and thus having a series of pin-holes very close together. The under paper is removed, and another one placed in its stead which we will suppose is to receive the red portion of the device. The workman transfers the outline of this red portion, by means of pin-holes penetrating through both papers to the lower one; and this is in its turn removed to make way for a third. Thus the operation continues, until as many pricked papers are prepared as there are colours; and it must be obvious from the nature of the method that these outlines are transferred precisely in the way in which they occur in the model pattern. This pattern thus becomes almost one mass of perforation, but it has answered the purpose for which it was intended.

The blocks on which these devices are next to be transferred are made with especial reference to the avoidance of warping or twisting. They are formed of two thicknesses of white deal and one of pear-tree wood, ranged so that the grain of the one shall cross that of the adjoining one, and thus counteract any tendency to distortion. The several layers, after being glued, are kept for some time in a powerful screw-press, as a means of ensuring as close a joint as possible; and when the whole mass, about two inches and a half in thickness, is dried

Cushions.

and planed smooth, the pear-tree surface is ready to receive the device. The pricked paper is laid upon the surface, and a little pounce or pounded charcoal, held in a bag which is dabbed on the paper, penetrates the pin-holes, and leaves a series of slight marks on the block sufficiently distinct to guide the pencil of the carver in working out the pattern. He then proceeds to cut away all the parts which do not form the device, carefully leaving the latter. Occasionally, if the pattern admits of it, small brass pins are inserted to make up the form, and brass pins are also fixed at the corners to guide the printer in joining the several portions which he prints, and in making the coloured portions to fall in their proper places.



Man in the act of Printing.

When the cutting of the set of blocks for one pattern is completed, the blocks are soaked with oil on their upper surface, to fit them better for the purpose they are to fulfil; and when all is ready, the printing-process commences. The workmen employ flat cushions similar to those represented in page 140. Each cushion measures about three feet by two and a half, and consists of a pad of flannel covered with a piece of floor-cloth. There are, for every pattern, as many of these cushions required as there are colours in the pattern about to be printed. A pot of paint, not so thick as that before spoken of, but still having a considerable degree of consistence, is placed beside each cushion, and a man with a brush lays a plentiful coating of paint on each; or at least there are one or more boys and men so engaged as to keep all the cushions supplied with sufficient rapidity.

The printer then takes one of the blocks, which he holds by a kind of leathern loop passing over the left hand, and dabs it down on the wet cushion, whereby a tolerably thick layer of paint is caught up by all the projecting parts of the block. He proceeds to the long bench on which a portion of the prepared canvas is spread out, and stamps the block down upon the cloth, whereby the first germ of the pattern is imparted. He hold in his right hand a very heavy hammer, with which he forces the block down into close contact with the cloth, as a means of ensuring the transfer of the paint. A second impression is then effected with the same block close to the first, care being taken that the two impressions shall form one continuous pattern. The printing thus proceeds until the whole width of the piece corresponding with the length of the bench is printed, as far as one width of this block can do it. Then ensues the application of the second block, used with paint of a different colour; the block being pressed successively over every part of the cloth as the first had been. In this second printing a twofold accuracy is required; first in respect to the successive applications of the same block across the width of the cloth; and next in reference to the junction of the colour in the proper relation to the colour of the preceding block; both of which are attained by attention to the guide-points fixed in the corners of every block.

When the whole of the blocks have been used in succession, and the entire printing effected across the cloth, and to a length of fifteen inches, the roller on which the cloth is wound is turned a little, by which the printed portion is allowed to fall down behind the bench, and a new portion to occupy the horizontal surface of the bench, after which the printing proceeds as before. There is a long aperture in the floor of the printing-room, through which the cloth is allowed to descend as it is printed, and to hang down freely exposed to the air: new portions are unrolled from time to time, as the printing advances, and the finished portions fall lower and lower.

If we examine a piece of floor-cloth, we shall see that there is nowhere a large smooth patch of paint, except in large plain patterns; but that the paint is laid on in little nodules or spots, technically called 'teeth,' from an eighth to a quarter of an inch square. The object of this plan is the following:—If a flat surface of wood, say two or three inches over, were dabbed down on a cushion covered with thick paint, the paint would be taken up very unequally, on account of a kind of adhesion between it and the block and cushion: it would be congregated more plentifully near the centre than near the edges, and would look patchy and unequal when thus laid on the cloth. Instead of this plan, therefore, the surface of the wood is broken up into a number of smaller surfaces by means of little channels which act as air-holes, and which enable the paint to be taken up equably. We see that each of these little spots or 'teeth' has the paint very thick in its centre; this contributes to the durability of the cloth; but if a similar thing were to occur with a surface an inch or two square, the effect would be very unsightly.

In printing passage floor-cloths of narrow but determinate breadths, the canvas is cut into strips after being prepared on the frames, and is then printed in the same manner as the other, with the exception that the border is printed by narrow blocks much smaller than the square ones. All the floor-cloths of either kind are allowed to hang suspended in the air in the drying-room until fit for use; when they are lowered, spread out on the floor, and cut or planned according to the purpose to which they are to be applied.

We may remark that floor-cloth is capable of being prepared in such a way as to form a very durable material for covering the roofs of houses. Some, indeed, has been so employed for nearly twenty years, and is still in good condition.

# CHAPTER VI.

## PIANO-FORTE MANUFACTURE.

THE manufacture of musical instruments partakes of so much diversity, that it is scarcely possible to treat it as a general department of art. Each particular instrument has its own peculiar mode of construction, and requires its own kind of mechanical arrangement. All, however, agree in this, that the most scrupulous attention must be paid to the selection of the materials, whether metal or wood. A pianoforte is perhaps, all things considered, the most complex and the most generally serviceable of all musical instruments: and we may take its manufacture for the subject of the present chapter.

Dr. Arne, when a young man, used to delight in practising by stealth after the family had retired to rest. He had in his bed-room an old *spinet*, from which, after muffling the strings to deaden the sound, he drew such tones as it could afford, and which have been described as "weak, wiry tones, between a cough and chirp, elicited by keys rattling like the dry bones of a skeleton."

If Arne, or any one who, like Arne, had been accustomed to the clavichords, the virginals, the spinets, and the harpsichords of past ages, could see a piano-forte of modern times, how great would be the change perceived! All these instruments, together with the psaltery, or dulcimer, act on the same principle—a principle which marks a separation between them and the violin on the one part, and the lute, the harp, and the guitar, on the other. This principle is the striking of a stretched cord, to produce from it the tone due to its length, thickness, and tension; yet, though fundamentally the same, how different in effect are these several instruments! The modes in which the principle is modified in the several forms of instruments are curious, and may thus be briefly glanced at. The ancient *psaltery* (nearly the same instrument as the modern *dulcimer* occasionally seen in our streets) was probably the original whence all the others have emanated; and, according to Mr. Hogarth, "consisted of a square box of small depth, over which was placed a sounding-board of fir, and on this sounding-board were stretched a set of strings of steel and brass, tuned to the notes of the scale." They were struck or played upon by two little rods held in the hands of the player. A great change was effected when the little rods were abandoned, and mechanism introduced whereby each string was provided with a lever which struck it. The lever constitutes the key of such instruments as this, and, in the form of an instrument called the *clavichord*, was provided at the hinder end with a little brass wedge that struck the string when the front end of the key was pressed down. To improve the tone elicited from the string the brass wedge was superseded by a quill, and the instrument then acquired the names of the *virginal* and the *spinet*. As a still further improvement, it was proposed to have two strings to every note, so as to increase the volume of sound: this involved a considerable increase in the complexity of the mechanism, and the improved instrument, under the name of the *harpsichord*, was in high repute during the greater part of the last century. At length occurred the happy thought of dispensing with the quills, and using little wooden hammers covered with leather, as a means of eliciting the tones of the strings, a modification which gave rise to the modern *piano-forte*, so named from the power of the instrument in producing "piano" and "forte," or loud and soft effects.

It was said a few years ago in the Westminster Review —"With a little allowable flattery of the truth, the book-case, in an inventory of the goods belonging to any well-ordered English house, might be designated as one of its necessary articles of furniture—not as one of its luxuries: the place of popularity among the latter being claimed by the piano-forte." Whether we rank it as an article of furniture or as a luxury, it is certain that the piano-forte has become diffused in an extraordinary degree in this country. Those who can carry their recollection back over a period of thirty or forty years, will remember the piano-forte as an instrument for the noble and the wealthy, sparingly seen in the houses of the middle classes: they will remember the gradual steps by which it has reached the domestic firesides of the bulk of the class just alluded to; and they will be prepared to expect that such an extension in the use must have brought along with it extensive plans of improvement, and equally extensive manufacturing arrangements: yet there are probably few, even of those who are familiar with the use of the piano-forte, who are aware of the complex mechanism of the modern instruments, or of the gigantic scale on which the manufacture is conducted.

The factories where these instruments are made are generally of very large dimensions, comprising open quadrangles surrounded by buildings. In many of these buildings the employment seems to the eye of a stranger to differ but little from common joiner's or cabinet work; while in others it has evident relation to musical arrangements.

In the open quadrangles are piles and stacks of mahogany, deal, beech, sycamore, and other kinds of wood used in the manufacture, every log and plank being marked to denote the time during which it has been exposed to the seasoning operation of the air; and in connexion with these there is always a 'seasoning-room,' which exemplifies the scrupulous care taken in the preparation of the wood before its employment in the manufacture. Every separate piece, after having been exposed to the air for some years, is before final use brought into this room, and kept for a long time exposed to a temperature of about one hundred degrees until the fibres are brought to a state of dryness as complete as can be obtained. The 'seasoning-room' is usually heated by hot water pipes; and it is also provided with a steaming-tank for steaming planks which are to be bent to any required curve.

The 'veneer-rooms' at such factories are places of importance. Logs for veneers are valued partly on account of the beauty of the pattern or figure, and partly on account of the size and soundness of the veneers which may be cut from them; and sometimes the two qualities are combined in a remarkable degree. It is generally known that Honduras mahogany is not so highly valued for cabinet-work as Spanish mahogany; it is therefore in the piano-forte manufacture used for some of the parts which are afterwards veneered with Spanish mahogany, rosewood, or some other kind of fancy wood. But some years ago a tree of Honduras mahogany far exceeded what Spanish wood could exhibit. The circumstance was thus alluded to in one of the volumes of the 'Library of Entertaining Knowledge,' a few years ago:—"Spanish mahogany is decidedly the most beautiful; but occasionally, though not very often, the Honduras wood is of singular brilliancy; and it is then eagerly sought for, to be employed in the most expensive cabinet-work. A short time ago Messrs. Broadwood, who have long been distinguished as makers of piano-fortes, gave the enormous sum of three thousand pounds for three logs of mahogany. These logs, the produce of one tree, were each about fifteen feet long and thirty-eight inches wide. They were cut into veneers of eight to an inch. The wood, of which we have seen a specimen, was peculiarly beautiful, capable of receiving the highest polish; and, when polished, reflecting the light in the most varied manner, like the surface of a crystal; and, from the wavy form of the fibres, offering a different figure in whatever direction it was viewed." *

Whatever form or value a piano-forte may have, it consists of a case containing stretched wires, which wires are struck by soft hammers, attached to the hindmost end of the finger-keys. This being the general character of the instrument, the various subdivisions are as follows. It was stated in a former paragraph that the *harpsichord* was an improvement on previous instruments, by having two strings to every note: this improvement has been retained in the piano-forte, together with the later one of having soft hammers instead of quills. The "tinkling grandfather of the piano-forte," as the *clavichord* has been called, had but four or five octaves; the harpsichord five or five and a half; but the piano-forte has extended its range to six and a half. These points being remembered, then, we may state—1st, that the *square* piano-forte has the strings horizontal, in a rectangular case, with two strings to each note, and a compass varying from five and a half to six and a half octaves. 2nd. The *cottage* piano-forte has its strings arranged vertically, reaching nearly from the ground to a short distance above the level of the keys: the case is much shorter than in the 'square;' there are two strings to each note; and the compass is generally six octaves. 3rd. The *cabinet* piano-forte is much higher than any other, except the *upright grand*, a form not now manufactured; the strings, two to each note, are ranged vertically, but, unlike those in the *cottage* form, are elevated wholly above the level of the keys: in general the compass is six octaves, but the most finished instruments have a compass of six and a half. 4th. The *grand* piano-forte is longer than any other; it is wider at one end than the other, and, unlike those hitherto mentioned, has the keys at one end; the strings are horizontal, and the chief feature whereby the instrument is distinguished is, that there are *three* strings to each note; the compass is always six octaves and a half, and there are thus upwards of two hundred and twenty strings. 5th. The *semi-grand* piano-forte is, as its name imports, a modification of the 'grand;' it has the strings horizontal; its case somewhat resembles that of the 'grand,' but it is shorter, has a compass of only six octaves, and has but two strings to a note. These are the five forms of piano-forte now made; and the manufacture of course involves certain modifications to suit the various forms. They, however, are not all of equal importance in a commercial point of view; for the 'squares' generally made are twice as many in number as all the rest put together.

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* 'Timber Trees,' p. 175. 1829.

The case, being a hollow box veneered on the outside, is made in a manner nearly similar to cabinet-work generally. In the 'square' form it is an oblong rectangle; in the 'cabinet' it is lofty; and in the other three forms it is modified in various ways. The most scrupulous care is taken in the selection of wood, not only in reference to its perfect dryness, but to the combining of two or three sorts together, so that each kind of wood may render its peculiar properties in aid of the others. Nearly all the workmen's benches are provided with a simple but valuable arrangement for pressing and keeping together the pieces of glued wood while drying. At a height of about four feet above the bench is a horizontal board or false ceiling; and the glued pieces being laid on the bench, a number of elastic wooden rods are placed nearly vertical between the false ceiling and the bench; being longer than the interval in which they are to be placed, they can only be adjusted by a slight bending or convexity in their length; and this bending gives them a very powerful pressure on the bench beneath or on the glued pieces placed on the bench. In some instances thirty or forty of these bent vertical rods are employed on one piece of wood. When the glueings are dry, a slight blow or jerk will remove each rod.

Without attending to the technical names applied to the various parts of a piano-forte, we shall, perhaps, be understood by general readers when we speak of the *framework* of the instrument as distinct from the mere outer case. If we open a piano-forte, especially a 'grand,' we shall see bars and rods and strengtheners of various kinds, placed in different directions, not only with a view to give form and stability to the instrument, but to resist the powerful strain to which it is exposed by the tension of the strings. This tension is truly extraordinary, and requires for its due appreciation a little consideration of the phenomena of a stretched string or wire. Let us suppose that a wire is wound round two pegs or pins placed a yard apart, and that it is merely brought into a straight line without any attempt at stretching it. If struck with a soft hammer, it will yield a low sound, due to a small number of vibrations per second; but if we wish to elevate the pitch of the tone, we can do so by increasing the tension or stiffness of the wire. A tuning-key being placed on one of the pegs to which the wire is attached, the peg can be turned round, and a portion of the wire wound on it; this necessarily increases the tension of the portion of wire extending between the pegs; the increase of tension increases the rapidity of vibration when the wire is struck, and this increased rapidity gives a more elevated pitch to the tone elicited. Now, in conformity with one of the laws of force, the wire pulls with a power equal to that by which it has been stretched; it tends to regain the state which it originally had, and by this tendency exerts a powerful dragging or pulling force on the pins to which its two ends are attached, and on the framework wherein the pins are inserted. This force is exerted by every wire, according to the tension given to it; and the aggregate force is surprisingly great. It is calculated that the two hundred and twenty-five strings or wires of a grand piano-forte exert a strain of more than twenty thousand pounds! This is in fact the force tending to draw together the two ends of the framework to which the wires are attached. It need hardly be observed, therefore, that the framework must be made with great strength. The various pieces of wood are in many places glued up so that the grain of one component part shall extend in one direction, and that of the other at right angles to it; different kinds of wood are used in different parts; an iron rod is placed here, an iron plate there; and contrivances of various kinds are introduced to give most strength where most strain will be experienced. The 'action' of a piano-forte (of which we shall presently speak) is, perhaps, more complicated in a 'cabinet' than in any other form; but the mechanism connected with the strings is far more complex in the 'grand.'

The mere attachment of each wire to pegs at its two ends is not sufficient for the adjustment of its tone. The whole length of wire is not allowed to vibrate when struck, but only a given length of it from one end to a pin inserted in a curved piece of wood. The adjustment of these vibrating lengths to the different strings is a matter of great delicacy, and may perhaps be rendered comprehensible by the few following remarks. There are three modes of producing an elevation of pitch in a vibrating string: 1st, by shortening the string; 2nd, by increasing its thickness; or 3rd, by increasing its tension. Now the manufacturer does not adopt any one of these methods of adjusting tones, to the exclusion of others: he avails himself of all. Twelve strings of the same length and thickness might be so different in tension as to yield the twelve semitones of an octave; twelve strings of the same thickness and tension might be of such different lengths as to yield the twelve semitones; or, lastly, twelve strings of the same length and tension might be made to produce these effects by having the thickness different. But in practice the tones produced by either of these methods would be very defective in character. Each degree of thickness, of length, and of tension, produces its own peculiar effects on the '*timbre*,' or quality of tone. If two strings of the same length and thickness were so stretched as to produce tones differing by an octave in pitch, one would be strained nearly to breaking, and the other would produce a dull, weak, and smothered sound. If, while producing these two notes, the strings differed only in length or in thickness, the qualities of tone would not be so much at variance as in the case just supposed; but still the required equable character of tone would not be produced. The plan adopted, therefore, is, to let the length, the thickness, and the tension, all vary together.

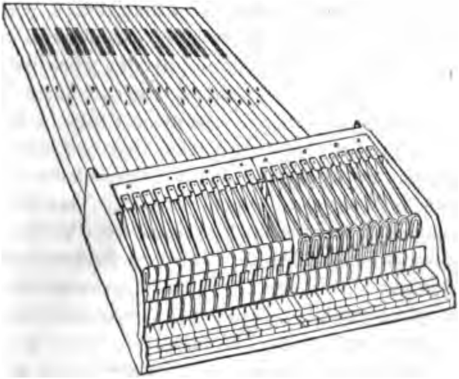
This explanation will enable us to understand the reason for the observed difference in the strings of the piano-forte. We perceive that the strings for the upper notes are not only shorter but also thinner than those for the lower; and we should find, though it is not perceptible to the eye, that the tension is likewise different. The thickness, the length, and the tension, all diminish (but not uniformly) from the lower to the upper notes; *tension* being here used to express the force employed in stretching the string to the required degree. In a grand piano-forte there are fourteen different thicknesses of wire; the smaller, for the upper notes, being plain polished steel wire; and the thicker, for the lower notes, being coated with a very fine coil of copper wire.

In adjusting the strings there are certain rules as to the thickness of wire selected for a certain note; and the vibrating length of each string is regulated by a curved piece of wood called a bridge, fixed to the sounding-board of the instrument. To make and adjust this bridge is one of the most delicate operations of the 'bellyman' or 'sounding-board maker.' The curve itself is regulated by a gauge to which the maker works: so is the position which it is made to occupy in the sounding-board; and so likewise are the order and arrangement of the pins inserted in it. These pins are so placed that the strings rest against them, each string being bent out of its rectilinear course by coming in contact with a pin. A portion of the string is thus effectively cut off, so far as regards the vibration; and the manufacturer is thus enabled, by the adjustment of the pins in the sounding-board, to give to the strings any vibrating length corresponding to the tones to be produced. So complex and important are these arrangements, that the strings of an improved grand piano-forte require nearly one thousand iron pins or pegs, each one inserted in a hole made with great exactness to its dimensions. The workmen called 'stringers' fix the proper strings to the proper pins. The wire is sent from the wire-drawer in coils about five or six inches in diameter, each coil containing enough wire for several strings.

Hitherto we have said nothing of the mechanism by which the strings are struck,—by far the most curious part of a piano-forte. This mechanism obtains the general name of the 'action;' and when we hear of 'square-action,' 'grand-action,' &c., we must understand these terms to allude to the particular mode in which the percussion is effected. It is perhaps scarcely too much to say that three-fourths of the improvements which the piano-forte has undergone during the present century have had relation to the 'action.' All the great firms for which the metropolis is distinguished in this branch of manufacture have brought forward some or other improvements in this respect; and their united labours have raised the instrument to such a stage of perfection, that—like the chronometer—there is little more to be wished for, unless indeed it were possible to obtain the *sustained* tones of the organ.

Cutting Piano-forte Keys.

The most obvious part of the 'action' is the key-board and its mechanism. Every ebony or ivory key is a lever, which, when pressed down at the foremost end, rises at the hindmost, and this leverage is the source of all the effects subsequently produced. A little examination of these keys will show that the ebony is solid, but that the ivory is merely a veneer or scale put on a substratum of wood. The white keys are made of carefully prepared lime-tree wood, which is cut after the pieces of ivory are attached. The preceding cut shows the appearance of the key-board while being cut up into keys. The pieces of ivory are shaped and prepared by the ivory-worker to the exact size for each key, and are glued side by side on the surface of the wood. The wood is marked out by a gauge, and is then cut up into parallel pieces for the keys, by means of a slight frame-saw. A notch is made in the stem or shaft of every



Treble-action of the Square Piano-forte.

white key, to receive the ebony key and its stem. When all the keys are cut, a little piece of mechanism is placed in one particular part of the length of each, to form a fulcrum.

To the hindmost part of each key is attached the mechanism whereby it is made to act upon the string; and this mechanism, to which the name of the 'action' is more particularly applied, presents a complexity of arrangement that will baffle everything like a popular description. Simple as the 'square' piano-forte is when compared with the other forms, yet the preceding cut will show that the 'action' attached to each key is anything but simple. This cut represents a 'square treble-action,' that is, such a portion of the keys and connected mechanism as belongs to about three octaves of the 'treble' or upper part of the instrument. This piece of mechanism is represented as viewed from behind, the most favourable position for displaying the intricacies of the 'action.' It is seen that there are a number of small pieces places at various angles, and acting upon one another by various species of leverage.

But this 'action' sinks into insignificance when compared to that of a cabinet piano-forte in its most improved form. We know of nothing, except the mechanism of a watch, to rival the latter in intricate combinations. One part of the mechanism attached to each key is to cause the hammer to strike on the string; another is to regulate the degree of strength or softness with which the blow is struck; a third is to prevent the rebound of the hammer after the blow; and others are to produce modifications of effect so minute that nothing but the most refined skill in piano-forte playing could render them either appreciable or necessary: indeed the advance of the manufacture, and the advance of the players in skill, reciprocally measure each other; for while on the one hand the resources of the instrument were never thoroughly known until a Liszt, a Thalberg, a Meyer, or a Moscheles developed them; so on the other hand these great players would never have been able to produce the exquisite effects for which they are so celebrated, unless the manufacturers had made important and repeated advancements in the progress of the instrument towards perfection.

Many persons may be familiar with the general appearance which the 'action' of an improved cabinet piano-forte presents before the silken covering is applied. Yet this 'action,' complex as it appears, can give but a faint idea of the minute details involved in the mechanism. Nearly the whole of the long slender rods, the levers, &c. here seen have nothing to do with the striking of the strings; they relate merely to the production of some of those delicate effects, those minute shades of tone, which are not sought for in the average style of instruments. The mechanism here seen forms the 'front action;' and on this being removed, another series, still more complex than this, is displayed; and on the removal of this latter, which is the 'action' properly so called, we see the strings themselves, the percussion of which is the object of all this intricate assemblage.

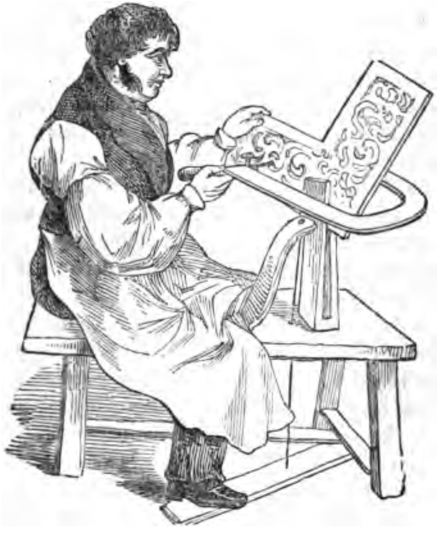
Perhaps the matter now under consideration could not be better illustrated, for general readers, than by stating the number of separate pieces concerned in this mechanism. In one of Messrs. Broadwood's most improved six-and-a-half octave piano-fortes the mechanism connected with the 'action' consists of about *three thousand eight hundred* separate pieces of ivory, ebony, cedar, sycamore, lime-tree, mahogany, beef-wood, oak, pine, steel, iron, brass, lead, cloth, felt, leather, and vellum. Every one of these has to be fashioned with the most scrupulous exactness, and as scrupulously adjusted to its place. Many of the pieces are not more than a quarter of an inch square, some even less. The qualities of all the varieties of wood are closely studied, in order to determine their particular aptitude for the different parts, and it is thus that so many as seven or eight kinds are used in the 'action' alone. One kind is preferred because slender rods made of it will not warp; another kind because the grain is straight; a third because it is hard and smooth; a fourth because it is soft and smooth; and so on. Some of the rods are as much as three feet long and only a sixth or seventh of an inch in thickness. To give the technical terms applied to all these little pieces would be of no use; for after saying that the key acts on the 'grasshopper,' and the 'grasshopper' on the 'under-hammer,' and the 'under-hammer' on the 'sticker,' and the 'sticker' on the 'hammer,' and the 'hammer' on the string, we have done but little towards explaining the particular construction and action of each.

When we say that all these minute pieces are fashioned and adjusted by hand, it will be readily conceived that an important part of the manufacturing arrangements has reference to them. Some of the workmen are 'key-makers,' who prepare the lime-tree of which the body of the key is made, glue on the pieces of ivory, cut the keys to their required widths, arrange the little pin or fulcrum, &c. Other workmen make the slender cylindrical rods of pine or of pencil cedar. Some are forming the 'hammers,' others the 'under-hammers,' the 'dampers,' the 'grasshoppers,' &c. An important and very curious part of the labour is the adjustment of the little pieces of vellum, cloth, felt, and leather. Vellum is used for the hinges of some of the minute parts; the two ends or edges of the vellum being glued into slits in the two pieces which are to be hinged together; and it thus forms a hinge peculiarly delicate in its action. The little pieces of cloth are used in various ways for subduing the rattling sound which pieces of mechanism would be apt to produce, and which would interfere with the tones of the instrument. To such a degree of refinement is this carried, that small holes not above a twelfth or fifteenth of an inch in diameter are lined with cloth, in order to give a smoothness to the motion of a wire which passes through the hole. The felt and the leather are principally employed as coverings for the hammers and dampers which come in contact with the wires, and which are thus covered to give mellowness to the tone. If a stretched wire be struck by a piece of wood or of metal, two sounds are heard; one due to the vibration of the wire itself, and the other to the blow which the striking substance gives: to get rid of this latter sound is the object of leathering and felting the hammers. The felt used for this purpose at Messrs. Broadwood's, and which is a beautifully soft white substance about a fourth or fifth of an inch thick, is said to be made from wool grown on Prince Esterhazy's estate in Hungary, the quality of this wool having been found admirably adapted, from its softness, for this purpose.

In speaking of the strings for the various forms of piano-forte, we stated that the 'grand' has three strings to each note; and that each of the other four forms has two. The adjustment of all these strings is an important matter, and devolves upon the 'regulators' and 'tuners.' It will of course be understood that in such a case the two or three strings belonging to one note must be tuned in unison; and to effect this the strings are, as may be supposed, of equal lengths and thicknesses. The object then is to bring them to an equal degree of tension, by which the tones may be of the same pitch. The persons employed at this avocation are such as are able, from accuracy of ear, to determine musical intervals with much precision. We may here remark that the 'regulation' involves something more than the determination of the musical intervals between the several tones: it relates also to the easy and proper action of the keys, and the general fitness of all the parts for the office which they are to serve.

A portion of piano-forte mechanism to which we have not yet alluded is that connected with the *pedals*, resembling all the other portions in the high degree of care necessary in the manufacture. These pedals serve two totally distinct offices, one of which relates to all kinds of piano-fortes, and the other to those only which are provided with three strings to every note. The first govern the 'dampers,' and their use may be thus explained. In order that the harmonies in a piece of music may produce their due effect, it is necessary that the preceding notes should not continue to sound long after the keys have been struck, else discord may usurp the place of harmony. For instance, if the note C were sounded, and the next note of the piece of music were D, the continued sounding of the C after the D has been struck would give the discordant interval of a second, which the ear cannot tolerate, except as a foil to more perfect intervals. Hence mechanism is provided whereby a soft hammer or 'damper' is made to fall on the vibrating string directly the finger is removed from the key, and this damping smothers the note by stopping the vibrations. As, however, it is desirable in some pieces of music to have the full effect of the vibrating strings after the fingers are removed from the keys, the player is enabled, by pressing his foot on a pedal, to remove all the 'dampers' from the strings, with which they do not again come in contact until the pedal is released. In some of the older square piano-fortes this adjustment is made by means of a handle situated near the left hand of the player; but we believe that in all the modern instruments a pedal affords the requisite leverage. The other kind of pedal, used only in grand piano-fortes, is employed for the purpose of removing one out of every three strings from the action of the hammers. If three strings were struck by every hammer every time that the key belonging to that hammer is played upon, the player could not obtain the *piano* passages which add so much to the grace and effect of music. There is, therefore, a provision for lessening the quantity of sound—for such is in reality the operation—by lessening the number of strings struck by each hammer. This is effected by shifting the entire key-board to a small distance from its usual position, whereby each hammer clears one of the three strings, and only strikes the other two. The foot-pedal effects this shifting by intermediate levers, and the player has thus the whole arrangement within his power.

Among the minor operations in the manufacture is the preparation of fretwork or open-cut boards for the front of some kinds of piano-fortes. This is effected in a very quick and elegant way. The device being marked on the board with chalk, the board is fixed vertically in a kind of vice, and, as represented in the annexed cut, is sawn by means of an extremely fine and thin saw, which follows all the turnings and windings of the chalk marks, penetrating to every angle, however acute, and severing the small pieces, the absence of which constitutes the pattern. The other ornamental features we must dis-



Fret cutter at work.

miss without any particular notice, as involving no principle but that which distinguishes common cabinet-work. We may, however, notice that the turned legs for the better kinds of instruments are produced by a beautiful lathe, the action of which is of a highly scientific order. An hexagonal or octagonal pattern is produced in a circular leg, by allowing the leg to remain stationary, and making the cutting tool revolve rapidly at such a distance from it as to cut away one-sixth or one-eighth of the surface. The cutting tool has at the same time a motion backward and forward in the direction of the length of the leg.

When the various component parts of the piano-fortes are put together, the tones regulated to something like accuracy, the exterior adorned with polishing, carved ornaments, &c., and all rendered nearly complete, they are conveyed to warehouses or rooms where the last adjustment is given to them.

## CHAPTER VII.

### WATCH AND CLOCK MANUFACTURE.

THE manufacture of these beautiful examples of ingenuity has many points which recommend it to our attention. The surprising extent to which the subdivision of labour has been carried, the value of the manufactured produce; the exquisite accuracy of the workmanship, and the peculiarities connected with the localization of this branch of art—all form interesting subjects for notice. It may be well to glance at the watch-making arrangements of Switzerland, and afterwards at those of Clerkenwell, before treating on the mechanical details of the manufacture.

Dr. Bowring, in a 'Report on the Trade and Commerce of Switzerland,' presented to parliament a few years ago, gave some curious details concerning the rise of the watch-manufacture in that country. It appears that about the end of the seventeenth century one of the inhabitants of Neuchâtel brought home a pocket-watch from a foreign country which he had visited; it got out of repair, and he gave it to a mechanic named Richard, who not only succeeded in re-adjusting it, but conceived the idea of making one for himself. After many trials and discomfitures, he succeeded in his object; and the product of his ingenuity excited the astonishment and admiration of all his neighbours: the emulation of others was roused; and by degrees the art of watch-making became introduced among the mountaineers, who had previously had very little other employment than that of a strictly agricultural character. During the first half-century after this new era, a few workmen only were employed in the art, and both the quality and the profit of the manufacture were but small, owing to the want of proper tools and materials, and to various commercial inconveniences under which the workmen laboured. By degrees, however, they succeeded not only in equalling the productions of other countries, but even in excelling them. As the manufacture of a good watch depends largely on the possession of good tools, the manufacturers of Neuchâtel came gradually to regard the making of the tools themselves as among the most important parts of their art; and they have ever since had considerable skill in this art.

About the year 1750 a few of the Neuchâtel merchants began to collect small parcels of the watches, and carry them to other countries and districts for sale. The system succeeded so well and the demand for Neuchâtel watches became so large, that nearly the whole of the inhabitants of the canton entered into the manufacture, in one or other of its numerous branches. The result of this was, that the face of the district underwent a great change: that which had before been rather a barren and bleak mountain district, became studded with well-built villages, connected by easy roads and media of communication, and inhabited by a prosperous population. The upper valleys of Neuchâtel formed the germ of this system, from whence it spread to the surrounding cantons. During the winter, which lasts at least half a year in that climate, the inhabitants remain almost wholly within-doors, employed in watch-making. It is supposed that, in one or other of the various branches connected with the manufacture, there are twenty thousand persons employed in the district of which Neuchâtel is the centre; by whom about eighty or ninety thousand silver watches, and thirty or forty thousand of gold, are made annually. The workmen carry on their labours at their own houses, working for those merchants or wholesale manufacturers who will pay them best: they are mostly landed proprietors on a small scale, cultivating their own ground in leisure hours, and living simply and frugally in the midst of their families.

Geneva is another great centre of the Swiss watch trade; indeed the manufacture has been carried on there for many centuries. The works and machinery are made chiefly in the neighbouring villages, and are sent to Geneva to be put together and finished. Chronometers, time-keepers, clocks, stop-watches, inferior watches, repeating-watches, musical watches, musical boxes, seals, and rings—all are made largely at Geneva, and give rise to an extensive commercial intercourse with other countries. Dr. Bowring takes the following view of the manufacture in relation to similar branches of industry elsewhere:—"A watch formerly had been an object indispensable for its use; it now became an article of taste and fashion; it furnished a convenient token for the expression of regard, and a present combining utility and taste with positive value. Under whatever form and for whatever purpose employed, the use of watches became the cause of unbounded activity in the workshops of Geneva. Many fashionable watches, those of a common description, and those of a still worse class, which sin against all true principles in their construction, those again remarkable for the singularity of their make, are for the most part an assemblage of parts destined to last but a little time, even from the first moment of their being put together, which time the watch-makers still further endeavour to shorten to the utmost of their power. The imperfections of these little machines are a certain warrant of their speedy destruction; besides which, the want of taste, the damage they receive in warehouses through inattentive and unskilful hands, or from a salt and humid atmosphere, all sorts of accidents and want of care on the part of the owners—are further causes which contribute powerfully to the destruction and demand for watches. If to the causes of destruction here mentioned we add the vast new sources of demand arising out of increased civilization, the wider spread of general prosperity, the local industry which pervades every spot, the commerce which penetrates the most remote corners, we shall find in these circumstances abundant reason to anticipate a constantly increasing demand for the watches of Switzerland, which perpetually struggles to maintain its pre-eminence for taste and moderation in price. It may therefore be presumed that this branch of industry contains within it the seeds of a firm and permanent prosperity, and is destined to increase rather than to decline."

The watch-trade between Switzerland and France is accompanied by some remarkable features. Almost all those which obtain the name of 'French watches,' although the movements may be made in Paris, are sent to Switzerland to be made up, and are then returned to Paris. A government duty is imposed on watches crossing the frontier, and this duty has given rise to an extraordinary system of smuggling. Sometimes a hundred or a hundred and fifty watches are sewn into the smuggler's waistcoat. More usually, however, dogs are employed as the smugglers. The dogs are trained to this office, and are conducted in packs to the frontier. They are kept without food for many hours, then beaten and laden, and then dispatched at the beginning of the night; they reach the abodes of their masters, which are generally selected at a distance of two or three leagues from the frontier, as speedily as they can, and are well treated and fed on their arrival. By this mode of proceeding, the dogs are led to exercise all their intelligence to get safely from the place where they are badly treated to the more welcome and hospitable home. The dogs are often trained to attack the custom-house officers who endeavour to stop them; and the difficulty of knowing how to deal with this crafty system is such, that the French government some years ago offered a reward of three francs for every smuggling-dog killed; and more than forty thousand of these ill-used animals were destroyed in ten years. We believe that changes in the nature or amount of the transit duties have lessened the prevalence of this vicious system.

A short glance at the Clerkenwell manufacture will not now be misplaced. Very little is known concerning the past history of watch-making in this district; but at the present day it is scarcely an exaggeration to say that nearly the whole prosperity and industry of the district are dependent on the making of clocks and watches. The 'movements' of a watch, or the wheels contained between the two brass plates, are made almost wholly in

Lancashire; but the making of the other parts, and the general adjustment of the whole, are carried on far more largely in Clerkenwell than in any other part of the kingdom, perhaps more largely than in all the other parts taken together. We will abstract from 'London,' No. 59, a few remarks on the subdivision of the manufacture.

When the 'movement' of a watch arrives in London, it is purchased by the 'watch-manufacturer,' who engages the services of a numerous body of persons to complete the watch from this skeleton. It is to be supplied with the 'motion-work' or mechanism in connexion with the hands; with a 'spring' and connecting mechanism; with an 'escapement' or apparatus for ensuring the uniform 'going' of the watch; with a 'case,' generally of silver or gold; with a 'dial,' usually enamelled, but sometimes of chased metal; with a 'glass' and with other appendages. The manufacturer gives these various parts to be made by certain persons who undertake definite portions; and these parties further subdivide to a degree of minuteness scarcely credible. The 'escapement-maker,' for instance, so far from being one workman who manufactures everything relating to an escapement, may be a 'duplex-escapement maker,' or a 'lever-escapement maker,' or a 'horizontal-escapement maker;' he may also have under him many workmen, each of whom is employed in, and is competent only to the manufacture of, some one particular part of some one kind of escapement. The enamelled dial of the watch, too, instead of being perfected by one man, passes through the hands of several: one man forms the dial out of sheet-copper; another coats it with the beautiful enamel; a third paints the letters and figures in enamel colours, and a fourth adjusts the dial to the other parts of the watch. The 'case,' in like manner, passes through many hands; for, besides the workman employed in actually making it, there is the 'secret-springer,' who forms the mechanism by which the two halves of the case close together; the 'engine-turner,' who engraves those curious devices which ornament the cases of some watches; the 'pendant-maker,' who constructs the loop and apparatus by which the watch is suspended from the chain, guard, or watch-ribbon. The 'hands' of the watch form a branch of the manufacture totally distinct from the others; so does that of the watch-key; and even that of the little 'index,' by which we regulate the 'going' of the watch when too fast or too slow. Some of the wheels of the watch are considered so far distinct as to have their teeth formed by workmen who do not cut the teeth of other wheels. The 'fusee,' likewise, a conical piece of brass on which the chain is wound by the watch-key from the barrel, is made by one who is wholly employed as a 'fusee-cutter.' In the 'jewelling' of a watch (a term which relates, not to the outward adornment by means of jewels, but to the use of hard gems as a material in which to make pivot-holes for the 'movement') some men are employed in preparing the gems, and others in making the pivot-holes.

This kind of dissection might be greatly extended; showing that the subdivision of employments is carried farther in this than in any other branch of manufacture. The 'watch manufacturer' is a tradesman who understands all these subdivisions, and is, therefore, competent to bring into one whole the labours of all these various classes and subclasses: he is, generally, a person possessing some considerable capital, as occupying the channel through which the purchaser deals with the actual makers. The watch trade of Clerkenwell does not exhibit large factories, where two or three hundred men are working in a body; it exhibits thirty or forty distinct classes of tradesmen; comprising, perhaps, three times that number of minor divisions, all living and working at their own homes, and contributing the various parts to a watch which is finally completed by the 'watch manufacturer.' Some of these thirty or forty are men possessing sufficient capital to employ in their workshops a considerable number of workmen, among whom they can carry out the principle of the division of labour to a still greater extent; while others are persons who work at their own homes, taking no more work than they can execute with their own hands, or perhaps with an apprentice.

We may now take up a few of the manufacturing details, especially those relating to large clocks, which have not hitherto been alluded to. The clocks placed in the turrets of churches and large buildings, as being the farthest removed in character, as well as in size, from pocket watches, require to have their prevailing features pointed out.

In the first place, everybody knows that a church-clock is generally fixed in the tower, or in some elevated part of the building; and it is also known that many churches exhibit clock-faces or dials in four different directions, so that the hour of the day may be observed by persons on all sides of the church. Now, there are, doubtless, many who entertain the opinion that in such a case there are four clocks, one for each dial or face, and who cannot conceive how all the four hour-hands and the four minute-hands can be moved by one clock. There are, also, it is probable, many different opinions as to whether the bell or bells which strike the hour, which chime the quarters, which (in some churches) play a psalm or hymn tune at certain intervals, which are tolled at a funeral, and which are rung at times of rejoicing, are all, or any, struck by the clock itself, or whether by men who act as bell-ringers. It may therefore be as well to state at once, that when a church tower exhibits four clock-faces, all at equal height, and opposite to the four points of the compass, all the hands are moved by the mechanism of one clock, which is placed in the midst of the tower, at equal distance from all the four faces. With respect to the bells, it may be stated that they are hung either over or under the clock, according to the size and general arrangement of the church tower; and that the hour is struck on a bell by a hammer moved by the clock; the quarters by similar mechanism acting on other bells; the psalm or hymn tunes by the action of a rotating barrel similar to those seen in musical snuff-boxes; and the tolling and pealing by bell-ringers, who pull ropes connected with the bells.

There is in the eastern part of London a church-clock which stands at a greater height from the ground than any other clock (we believe) in or near the metropolis, not even excepting that noted City monitor St. Paul's clock, and which presents four very large faces on the four sides of the tower. This clock is that of St. Ann's church, Limehouse; and we perhaps cannot do better than make it the text for what we have to offer on this subject.

The value of room in a church tower is such that the approach to the bell-loft and clock-room is generally narrow and awkward to a degree which renders the ascent anything but inviting. The short, narrow, steep, dark, and winding stairs; the loop-holes through which the wind finds entrance in a cutting blast; the small doors and outlets; the dreary loneliness, and no less dreary echo of the footsteps; the cold and the dust — all are familiar to those who have ascended to the upper part of St. Paul's cathedral, and are almost equally observable in other church towers, including the one to which our attention is here directed.

On ascending to a height of about a hundred and thirty feet, in the tower of Limehouse church, we find ourselves in the 'clock-room.' This is a square room, bounded on the four sides by the thick walls of the tower, and having a wooden flooring on which the clock rests. The light is very limited, and it is not till the eye has become a little accustomed to the gloom that the objects in the room are discernible. The clock is seen to be enclosed in a wooden case about eight feet high, six feet wide, and four feet deep, the two opposite sides of which may be thrown open by means of folding-doors, thus exhibiting a complicated assemblage of wheel-work and other mechanism within.

The clock contains about thirty wheels, some of which govern the motion of the hands; others, the striking of the bell.

The clock is placed in the centre of the room, and a visitor can walk entirely round it, without interfering in any way with the mechanism connected with the clock-faces visible outside the church. It may then be asked, how are the hands on these faces brought into connection with the moving machinery? We find an answer, by observing the arrangements overhead, as we pass round the clock. There is a horizontal bar of wood extending from the clock on each side to the wall opposite to it; and on this bar is placed an iron rod, which is set in rotation by the clock, and, in its turn, causes the hands to rotate round the clock-face on the outside of the tower. There are four of these rods branching out from the clock in a horizontal position towards the four points of the compass, each rod governing the movement of one pair of hands. On looking downwards from the clock-room we see the mechanism by which the clock is set going, and also that by which the bell is struck every hour. There are neither chimes nor quarter-hour bells at this church, so that the striking machinery connected with the clock has relation only to one bell. Examining a little more closely, we see that the moving power is a heavy iron weight, suspended by a rope which coils round a barrel, and that the instrument which strikes on the bell is an iron hammer connected with a series of levers and rods.

Such are the chief points which become observable in the clock and bell tower of the church here alluded to; and if any other of the metropolitan churches were similarly visited, they would be found to contain the same general parts, modified by the circumstances in which they are placed. Some, in which only one clock-face is required, would not have the four connecting rods branching out horizontally from the clock; others would have the bell and striking machinery above the clock instead of below it; others would be without a wooden case, provided the room were close and free from dust; while others again would have additional striking machinery, for quarters or chimes.

Thus far for the general arrangement; and now we may attend a little to the manufacture and mode of action of these several parts. Not the least remarkable of the circumstances connected with church clocks and bells is the very narrow limits within which the manufacture is confined. There are, we believe, only two establishments in the metropolis at which church-clocks are made. The cause for this limitation may perhaps be sought in the comparatively small number and long duration of these pieces of mechanism. New churches shoot up but slowly, and old ones do not have a renewal of clocks and bells except at long intervals.

Neither a pocket-watch, nor an eight-day dial, nor a common Dutch clock, will exactly convey an idea of the construction of a church-clock; for, instead of being moved by a spring, as the two former, it is moved by a weight; while on the other hand its accurate finish of workmanship is wholly unrepresented in the Dutch clock. Generally speaking, the framework of a church-clock is made of iron, the principal wheels of brass; and some of the pinions and finer work of steel. The arrangements of the maker are therefore regulated according to the number and parts of the clock made at his factory. Whoever has seen a watch-maker at work, must have observed the extreme minuteness of his tools and working apparatus; but such a person is not strictly a *maker* of watches; he only puts together, and adjusts and repairs, the various parts which have been made by many different hands. In the clock, manufacture, and especially in church-clocks, this subdivision of employments is not carried out to nearly so great an extent. At the church-clock factories almost every part of the mechanism of a church-clock is made within the establishment, except the rough-castings in iron and brass. In the smith's shop all the forging and filing of arbors, bars, and other works of iron are effected; as well as the case-hardening of the finished pieces. In the wheel-cutting shop is carried on the beautiful operation by which the teeth of wheels—that important department of all such manufactures as this—are cut. In other shops the general fashioning and adjustment of the numerous pieces which form a clock are effected, aided by various pieces of mechanism, such as lathes, for turning brass, iron, and wood, drills, revolving machinery, polishing apparatus, &c.

Without attending particularly to the classification which a clock-maker would lay down, we will separate a church-clock and its mechanism into five parts—1st, the moving-power; 2nd, the 'movement,' or going wheels; 3rd, the regulation, or pendulum arrangements; 4th, the indication, or mechanism connected with the hands; and 5th, the striking machinery. Any attempt to follow the minute details of clock-making would be quite out of the question, and will not be made here.

First, then, the *power*. Every child knows that the old familiar clock, which has perhaps formed one of the household inmates as far back as he can remember, is 'wound up' occasionally, not by turning any wheel or handle, but by elevating an iron weight to the height of the clock; almost every child knows that the little pocket-watch, whose tickings excite such astonishment in his mind, is 'wound up' by means of a very small key; but there are many children of larger growth who are utterly at a loss to know what this winding-up really means. The main body of a clock or watch consists of many wheels which work one into another, insomuch that if one wheel moves, the others are drawn into motion by it. But there must be something to impart this motion in the first instance; and this is called the *power*. We know that if the pendulum of a common clock be stopped, the clock is stopped at the same moment; and that the movement of the clock is renewed when the oscillations of the pendulum are renewed. Hence many persons may suppose that the pendulum is the source of the clock's motion. Again, there are stop-watches in which, by moving a little pin, the watch may be made to stop; and then, by a contrary movement, the going of the watch may be renewed; and hence the pin seems to be the source of motion. But both these suppositions are erroneous. In both these cases of stoppage, the rotating wheel-work is checked by a small piece of mechanism, and the motion is renewed when the check is removed; but the *production* of the motion is a totally different affair. In a common pocket-watch, the key by which the winding-up is effected is placed on a small piece of mechanism called a 'fusee,' from which a chain extends to a brass box or barrel. This barrel contains a fine and highly tempered steel spring, which becomes coiled up very tightly by the rotation of the fusee and the winding on it of the chain from the barrel. This tight coil is so different from the natural state of the spring, that the latter exerts a powerful pulling force in its endeavours to regain its original position; and this force tends to make the barrel in which it is fixed rotate, because by this means only can the original state of the spring be regained. When once the barrel is made to rotate, that rotation can be communicated, by toothed wheels, to other mechanism. Such is the source of power in pocket-watches, in chronometers, and in the dials which are now so much used in public buildings and large apartments.

In church-clocks, turret-clocks, and common house-clocks, there is no such spring as that alluded to in the last paragraph. There is a line or rope, descending perpendicularly from a particular part of the wheelwork, and having an iron weight suspended from its lower extremity. The iron appendage of course exerts a gravitating force in proportion to its weight, and descends gradually; but from its mode of attachment, it cannot do so without causing the rotation of a barrel round which the cord is wound. When the pendulum is stopped, either purposely or accidentally, a catch or detent falls into such a position as to prevent the rotation of the barrel; but this obstruction being removed, the barrel rotates so long as the weight descends; and this rotation is communicated, by toothed wheels, to other mechanism. When the weight descends to the floor, or when all the cord is unwound from the barrel, the clock must stop; but before this time arrives the machine is wound up by causing the barrel to rotate in an opposite direction, by which the cord becomes re-wound upon it, and the weight elevated.

In a house-clock the weight is so small that the winding-up is effected easily by pulling a small handle; but in larger clocks the aid of a winch or windlass is required. The length of the cord is proportioned to the diameter of the barrel, and to the time which the clock is intended to 'go' between each two windings; and is, in a church-clock, very considerable. At the Limehouse clock, the time of going is, as in most church-clocks, eight days, and the weight by which the barrel is made to rotate amounts to about sixty pounds. The line does not fall perpendicularly from the clock to the weight, but passes over two or three pulleys for economy of space.

2nd. The '*movement*,' or the going-train of wheels. The makers of clocks and watches apply the name of the 'movement' to the assemblage of wheels which are put in motion by the moving-power. Technically, those wheels which are connected immediately with the hands, with the pendulum, or with the striking machinery, are excluded from this group; but our purpose here is to say a few words respecting the wheelwork generally.

Almost every wheel in a clock has teeth or notches cut in its circumference. Sometimes these teeth stand out radially from the edge; sometimes they are perpendicular to the plane of the wheel; sometimes they nearly resemble the teeth of a saw; but whatever be the varieties, a glance at the interior of a clock or watch will show that almost every one has these indentations in some form or other. This is one of the modes adopted in general mechanism, for communicating motion from one wheel to another; pulleys, straps, and bands being inconsistent with the minuteness of a clock or watch. In some cases two adjoining wheels work into each other, the teeth of one interlocking in those of the other; but in other cases a small number of teeth are cut in the pinion or axis of one wheel, which work in the teeth at the circumference of the other wheel; and indeed it is in this latter way that a difference of velocity is generally attained. If, for instance, a wheel with fifty teeth work into a pinion of ten teeth, the pinion will rotate five times as fast as the wheel, and thus becomes a source of higher velocity. The great point of attainment in the 'movement' of a clock or watch is, that one particular wheel shall rotate exactly once in an hour; this being effected, the arrangement of the hour and minute hands becomes easily determined. The proportions of the teeth in all the wheels and pinions is therefore so fixed as to lead to this rate of movement. In the Limehouse clock the barrel, which is a solid cylindrical block of elm, about eighteen inches in diameter, is attached at one end to a toothed wheel, about two feet in diameter, which rotates with it; and this rotating wheel forms one in a train which leads to the hourly rotation of one particular wheel.

The manufacture of the 'movement' or 'going-train' of a clock or watch consists, therefore, principally in the careful preparation of toothed wheels and pinions. These wheels are made sometimes of brass, and in others of gun-metal, while the pinions are of case-hardened steel. The wheels are brought to the clock-factories in a very rough state, just as they are produced by the caster or founder, consisting merely of a circular rim, connected more or less with the central part through which the axis is to pass. The whole manufacture of the wheel from this rude germ is then effected in the shops of the factory. There are lathes for giving to the wheel a perfectly true periphery, by means of sharp steel tools; various pieces of mechanism for shaping, smoothing, and polishing every part of the surface; and, lastly, a very beautiful engine for cutting the teeth.

In these last-mentioned machines a horizontal rod or bar is made to rotate on its axis with great rapidity; and at one part of its surface is fixed either a wheel or a small sharp piece of steel, corresponding in shape to the teeth about to be cut in the brass wheel. The latter is fixed horizontally on a stand, at such a distance from the cutter that the latter can just reach it in the course of its rotation. The amazing rapidity with which the cutter rotates enables it to cut through the brass with great ease, the pressure or contact being regulated by a lever which the workman moves with his right hand. Cutters of various shapes and sizes, but all made of hardened steel, are provided for the cutting of different kinds of teeth. When one tooth is cut, the workman shifts the wheel round a little, to present a new portion of the circumference to the action of the cutter; only one tooth being cut at a time. The extent of this shifting is managed thus:—A brass plate, lying horizontally on the bed of the engine, is marked with a great number of concentric circles, each of which is divided into a number of precisely equal parts, the number being different in the different circles. One circle, for instance, is divided into forty-eight parts, another sixty-four, a third seventy-two, and so on, as may be found most advantageous. If a wheel is to have any number—say sixty-four—teeth in its circumference, a lever is so adjusted that a sharp point at its extremity shall just reach the circle which is divided into sixty-four parts, and as there is a little hole made in the plate at each of these divisions, the sharp point attached to the end of the lever will drop into all these holes in succession, as the plate revolves. The revolution of the wheel which is to be cut causes also that of the divided plate, and the workman knows, by the dropping of the sharp point into one of the little holes, when he has shifted round the wheel to a sufficient distance.

No one who has not closely attended to the matter can conceive the difficulty which has been experienced in thus dividing circles into any number of rigorously equal parts. All the resources of art shown by Ramsden, Troughton, and other eminent mathematical instrument-makers, have been required in the division of circles for astronomical instruments; and although such strict accuracy is not required in common clock and watch wheelwork, yet the amount of skill required and shown therein is sufficiently striking.

Whether the teeth be cut in brass, in gun-metal, in iron, or in steel, whether they are in the wheel itself or in the pinion, and whatever their shape may be, the cutting is effected nearly in the same way, and is succeeded by various finishing and polishing processes requisite for the accuracy of the wheel's motion. Here then we may leave them and proceed to,

3rd. The *indication*, or mechanism connected with the hands. The dial-plate, or rather, face of a large church-clock is generally of wide dimensions, as a means of making its indications conspicuous from below. The four clock-faces at Limehouse church, for example, are each thirteen feet in diameter, with hands and figures of proportionate size. The hands are made of copper, and weigh about sixty pounds the pair. Each hand has, at the extremity opposite to the pointed end, a heavy piece of copper sufficient to act as a counterbalance, and to allow the hand to obey the motion of its axis; this counterbalance is generally painted black, to render it less visible. The arrangement of the mechanism connected with the hands may perhaps be understood from the following description:—At the upper part of the clock is a horizontal wheel, which gives motion to four wheels at right angles to it. These four wheels are connected respectively with the four horizontal rods, which proceed from the clock to the faces. Each of these rods, which are about eight feet long and three-quarters of an inch thick, rotates once in an hour, and communicates that rate of motion to the axis or pinion on which the minute-hand is placed. Other wheel-and-pinion work so modifies this motion as to make another axis rotate once in twelve hours; and on this latter is fixed the hour-hand. It will therefore be seen that the sole source of the movement of the hands is the rotation of the iron rods which extend across the clock-room, and that the mechanism of the clock sets these rods revolving.

Of the face itself we may observe, that in most instances it is made of copper, painted and gilt in a more or less ornamental manner. Others are made of slate; and in some cases the face consists of a circular depression cut in the stonework of the clock-tower, with figures either painted and gilt on the stone, or cut in relief. The making of the wheels and pinions connected with the clock-face is the work of the same class of persons as those employed in the 'movement' wheels; while the decorative parts devolve upon the 'clock-face gilder.' The dial-plates used for the smaller kind of clocks are very different from these: in some cases they are made of brass, brought to a fine surface, and silvered; with figures and inscriptions cut in the metal by the 'clock-engraver;' while in other instances the face is made of sheet-copper, coated with enamel, and having figures and letters painted in enamel of a different colour, the work of the 'dial-plate enameller' and the 'enamel-painter.'

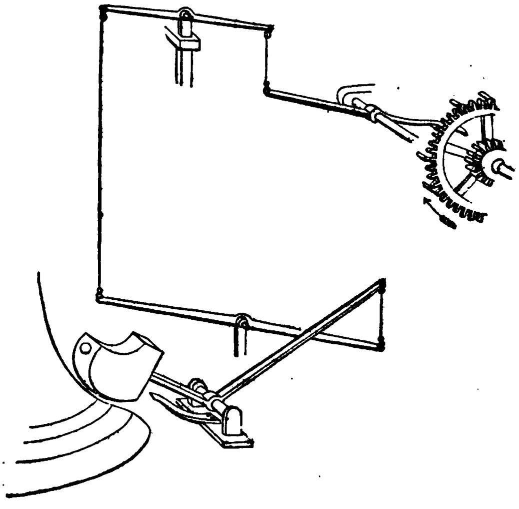
4th. The *regulation*, or pendulum arrangements. We cannot perhaps better illustrate the use of these portions of a clock's mechanism than by endeavouring to answer the following question: Why does not a clock run down in a few hours, when so heavy a weight as sixty or seventy pounds is constantly urging it? Such would be the case if there were no regulating machinery. In a common vertical pocket-watch we see under a perforated cover a bright steel wheel rotating, or rather vibrating, horizontally; in a common clock we see instead of this a pendulum oscillating to and fro. The mechanism in the first case is known by the general name of the *escapement*, or *'scapement*; and however different in appearance, the object is the same as that attained by the pendulum of a clock. A spring with a given degree of tension, and a pendulum of a given length, each requires a certain time for the performance of an oscillation; and this important law is made to regulate the movements of the wheel-work in a clock or watch. The steel wheel in a watch is called the 'balance-wheel,' and is governed by a fine spring lying beneath it; but we will here confine ourselves to the pendulum arrangements of a clock. All church-clocks have a long wooden pendulum or staff, to the lower end of which a mass of iron is attached. In the Limehouse clock, for example, the pendulum rod is about thirteen or fourteen feet long, and to the lower end of it is attached a mass of cast-iron shaped like a double-convex lens, about thirty inches in diameter, and weighing two hundred pounds. This is suspended from the framework above, and acts in the following manner:—As the wheels revolve, one part of the mechanism gives an impulse to the pendulum, by which it is set in motion; as soon as that impulse has ceased, another urges the pendulum in the opposite direction, and thus the oscillations are produced; but as the pendulum, from the law which governs its movements, has a tendency to make all its oscillations in equal time, it acts as a regulator to the motion of the wheels, and gives it uniformity. As a ball rolling down an inclined plane would move more and more rapidly every second, so would the rotation of the wheels in a clock increase in rapidity every second, were it not that the pendulum absorbs, as it were, all this increase of velocity by increasing its own extent of oscillation, leaving the *time* between every two oscillations unaltered. It is this equality of time in the movements of the pendulum which produces and maintains equality in the movements of the wheels.

The mechanism connected with the pendulum is not very extensive. The rod is a plain piece of wood, squared and smoothed for the purpose. The mass of iron, or 'bob,' is cast to the required shape and size, and has an adjusting arrangement by which it can be attached to the rod at any part of its height. In some church-clocks there is a graduated arc to measure the extent of the vibrations, which varies with the moving-power. At the upper end of the pendulum are small pieces of mechanism, in iron and brass, by which the rod is brought under the influence of the wheelwork, and set into oscillation. The 'bob' of a church-clock pendulum, from the necessary length of the rod, is in most cases beneath the room in which the clock itself is contained.

5th. The *striking* machinery. Our clock has hitherto been a silent monitor. We have offered a few items of explanation as to the manner in which it shows to the eye the progress of time; but there is an appeal to the ear which is equally worthy of notice. Every one knows that church-clocks differ greatly in the number and frequency of the sounds emitted from the bells. Many clocks only strike the hour, proportioning the number of strokes to the hour of the day; others, in addition to this, announce the quarters, by two, four, eight, or some other number of bells, all bearing a certain musical relation one to another; and a third kind play some particular hymn or melody at certain intervals of time, on eight or ten bells. But all church-clocks, with very rare exceptions indeed, have a bell on which the hour is struck.

It will easily be conceived that if a bell be hung in a particular spot, and a lever with a hammer at the end be placed near the bell, the lever may without difficulty be so influenced by the wheels of the clock as to cause the hammer to strike the bell. But to cause exactly an interval of an hour to elapse between two such strikings, and to make the number of blows on each occasion correspond with the hour of the day, require mechanism almost as complicated as that by which the indications of the hands are produced. Still greater is this complication when the clocks chime the quarters; and when a regular melody is performed on the bells the arrangements are proportionally more intricate.

In the first place it must be clearly borne in mind that there is a separate moving-power for the striking-machinery, similar in principle to that which impels the going-train. In an eight-day dial, for example, there is one spring-barrel and fusee for the going-train, and another, nearly the same in form and size, for the striking-train. In a church-clock, and in common Dutch clocks, there is one iron weight for the going-train and another for the striking-train, each weight having a cord and barrel appropriated to itself. If we notice the movements of a common domestic pendulum-clock, we shall see that while one of the two weights is continually descending at a slow rate, the other descends only while the clock is striking; it is the descent of the last-named weight which causes the striking of the clock, and this striking would be continuous if there were not checks to the descent of the weight. For a large church-clock, where the tones of the bell could not be clearly elicited except by blows from a heavy hammer, the moving-power of the striking machinery greatly exceeds that of the going-train. In the Limehouse clock the going-weight is about sixty pounds, whereas the striking-weight is a mass of iron weighing five hundred pounds, and the hammer-head fifty-six pounds. This heavy mass is attached to a rope which winds round a solid wooden barrel, of nearly the same diameter as the barrel before spoken of, and this barrel gives motion to a train of wheels by the customary tooth-and-pinion work. The motion, however, is checked by a catch or detent, except at the termination of each hour, when a curious piece of mechanism connected with the going-train releases the striking machinery, allows the weight to descend, and causes the hammer to strike the bell. Whether the bell be above, below, or at the side of the clock, the connection between the striking-wheels and the hammer is easily made by levers and pulleys; at the Limehouse clock the bell is beneath the other parts of the mechanism. The mechanism in immediate connection with the hammer and bell of the Limehouse clock is shown in the annexed cut.



Striking-apparatus of a Turret-Clock.

But although the release of the striking machinery causes the descent of the weight and the percussion of the bell, yet this does not determine whether the strokes shall be one or many. This is determined principally by two pieces of mechanism called a 'snail' and a 'rack,' the intricate action of which it would be in vain to attempt to explain here. Suffice it to say, that the time during which the striking weight is allowed to descend varies at different hours of the day: it being sometimes only long enough to permit one blow to be given by the hammer on the bell; and at another time long enough for twelve such blows.

When the clock indicates the quarter-hours on two or more bells, an additional piece of mechanism is necessary, which releases the hammers of those bells every fifteen minutes. The bells are more numerous, and the mechanism more elaborate, when they are designed to produce a musical chime or a melody at stated intervals.

The merry peal which marks the holiday or the day of festivity is not rung by machinery connected with the church-clock, but by men, who pull ropes by which hammers are made to strike on a set of bells; each man attending to one bell, and the whole regulating their proceedings according to the rules of the curious art of bell-ringing. But where a melody is performed at fixed hours every day, then are the bells sounded by mechanism connected with the clock. He who hears the 149th Psalm played on the bells of St. Clement's church, or the tunes on the bells of other metropolitan churches, must not confound these performances with the ringing of a *peal* of bells.

In some churches the bells play only one tune, at certain fixed hours of the day; in others there are seven different tunes played, one for every day of the week, each tune being repeated either six or eight times within the day to which it belongs. Such is the case in a clock constructed for Christchurch, Hampshire, six or eight years ago; there is an octave of eight bells, which play seven different tunes, the tune being changed at midday.

How are these tunes played? Such a question has doubtless occurred to many persons, and is deserving of an answer. In a musical clock, as in a musical box, there is a barrel studded in various parts of its surface with small pins or pieces of wire, placed apparently in a most unsymmetrical manner. These pins, during the rotation of the barrel, come in contact with the small springs in the musical box; but in the clock they catch against small levers connected with the hammers which strike the bells. Every pin moves a lever with sufficient force to enable the hammer to strike the bell; and therefore the artist's object is to place the pins in such order on the surface of the barrel as to lead to the striking of the bells in the proper order to form a tune, the bells being attuned to regular musical intervals.

In musical boxes there is a curious adaptation of the principle on which the 'pricking' of the barrel, or the insertion of the pins in their proper places, is regulated. In modern church-clock factories the pricking is effected by a very beautiful machine; but a description of the old method adopted, though too rude for modern purposes, will perhaps be more readily understood by persons unaccustomed to machinery. A piece of writing-paper was taken, of such a size as to cover exactly the surface of the barrel; and on this were drawn, in a direction perpendicular to the axis of the barrel, as many parallel lines as there were notes in the tune, the lines being equidistant and corresponding to the levers which moved the hammers. They were marked at each end with the letters or notes of the gamut which they represented; and, according to the number of bars in the tune, as many spaces were made by lines drawn equidistant and parallel, intersecting the others at right angles. The junction of the ends of the paper, when applied round the barrel, represented one of these bar-lines. The spaces were again divided into smaller parts, for the minims, crotchets, and other notes in the tune, by lines parallel with the axis of the barrel. While the paper was lying on the table, the notes in the tune proposed to be laid on the barrel were marked by black ink dots on their respective lines, and in the same order as the bars of the music. After this was done, the paper was pasted on the barrel; and the note-lines then appeared like so many circles traced round the circumference of the barrel, while the bar-lines lay longitudinally on the surface of it. By this means the black ink dots were transferred and marked on the barrel by a punch or finger-drill, and the pins inserted at those spots.

But where many tunes are played by one barrel, this primitive mode is inefficient. The principle, however, may be understood from it. The barrels 'pricked' for several tunes by the modern machine are so connected with the mechanism of the clock as to shift a little when the tune is changed, so that the hammers may be acted on by a different set of pins from those in use during the performance of the former tune; indeed this shifting of the barrel is the circumstance which changes the tune.

## CHAPTER VIII.

### CABINET-MANUFACTURE.

The kind of industrial art by which the usual forms of domestic furniture are produced, is such as relates mostly to the preparation of woodwork by the saw, the plane, and other similar tools. All the costly cabinets, sideboards, buffets, tables, and other articles which have so uniformly attracted attention by their varied beauty, depend on this branch of industry more than on any other; for gold, marble, and ivory are rather decorative appendages than substantive materials for such purposes.

Cabinet-work is rather the occupation of workshop-artisans than of factory-artisans, if we may use such terms: that is, the men are employed in workshops of moderate size, and not in huge factories provided with all the appliances of steam-engines and machinery. There are, however, a few examples in London, Newcastle, and elsewhere, of such manufactures being conducted very much on the factory-system; a central courtyard being surrounded by the buildings in which the processes are conducted; and a degree of supervision and regularity being observed to a much fuller extent than in workshops of a smaller kind.

To describe minutely all the routine of cabinet-making operations is out of the question here; but the broad outlines may be given. The timber employed is cut up into thin 'veneers,' or into larger pieces, according to the purposes to which it is to be applied. How a log is cut up into planks at a sawpit is too well known to need description; but the mode of applying machinery to this purpose is curious.

Without going into the minutiæ of construction, we may briefly describe the action of a saw-mill, such as is frequently used at the present day. A number of saws are fitted vertically into a frame, truly parallel one to another, and at distances of one, two, three, &c. inches, according as the log of mahogany or other timber is to be cut into planks one, two, or three, &c. inches in thickness. These saws are made immoveable in the frame, but the frame itself works up and down like the sash of a window. The log is laid horizontally, and one end of it brought up to the toothed edges of the row of saws. The frame containing the saws is then worked up and down, the saws all cutting simultaneously into the log; and as the latter is placed upon a bed or carriage sliding on the floor of the mill, and sufficiently narrow to pass through the opening in which the saw-frame slides up and down, it is pushed onward as fast as the saws cut, until the whole length of the log has been thus operated on. As the saws are ranged in a perfectly parallel manner, and as the log is moved onward with the greatest regularity, the cuts are made more truly than they could possibly be effected by hand, at the same time that several are being made at once instead of one. So much have the advantages of this mode been felt of late years, that almost every considerable timber-yard now contains a saw-mill. But Mr. Brunel afterwards introduced the circular saw, by which continuous cuts are made in the log of wood.

It is interesting to trace the manner in which lustre, figure, and colour in the fibre, lead to the selection of different kinds of wood for cabinet-work. Mr. Aikin, in one of his illustrated lectures before the Society of Arts, entered upon this matter; and we may here give a few of his results.

The first cause of difference in different woods is the nature of the fibre. The fibrous portion of wood, when examined with a glass of moderate power, appears to consist of bundles of fine filaments, more or less parallel one to another. These filaments are more or less translucent, when held between the eye and a bright light, and have a smooth polished surface,—a structure which produces a variation or play of light according to the angle under which the fibres are viewed, the degree of light or the lustre depending on the number of adjacent fibres that have their reflecting surfaces strictly parallel. When the fibres proceed nearly in right lines, their lustre is very different from that displayed by tortuous fibres. In some kinds of wood, such as the sycamore, and still more in ash and mahogany, the bundles of fibres meet with obstructions which throw them into gently waving or tortuous directions. The parallelism thus becomes disturbed more or less in some parts, while it is uninfluenced in others; and thus result some of those beautiful variations of lustre which the same piece of wood presents. In the horse-chesnut and in the box the fibres are not sufficiently parallel to produce great play of lustre on the surface, although individually they have considerable brightness.

The next source of variety is afforded by those thin plane portions of the woody structure which vegetable physiologists term the medullary plates. The structure of these parts is invisible to the naked eye; but when viewed through a magnifying-glass it appears to be composed of fine granular matter, which a powerful microscope further resolves into a cellular structure. This substance is in general dull and incapable of receiving a polish, but it often gives great beauty to the fibres which pass over and between the medullary plates, by forcing them to assume a perfectly regular and parallel arrangement. "In the oak," says Mr. Aikin, "the medullary plates are much larger than in any other wood that I have seen; and when their broad side is brought to the surface by a section a little oblique to the direction or run of the plates, they have this peculiarity, that they are dull when the fibrous part reflects the light, and, on the contrary, exhibit a bright silky lustre when the fibres are dull. In all the coloured woods that I have examined, with one exception, the colour of the medullary plates is much deeper than that of the fibres, and sometimes differs even in kind, so that when viewed ir different lights they present different colours, like a shot silk." In the wood of the plane-tree the medullary plates are large, distinct, and of a rich chesnut-brown colour, while the fibres are dull, and nearly white. In the Botany Bay oak, in beef-wood, and in common elm, the fibres present more lustre than the medullary plates. In the laburnum the relative colours are very remarkable, the medullary plates, which are large and very distinct, being white, whereas the fibres are dark brown. In satin-wood the medullary plates are reddish brown, and the fibres, which have a silky lustre, are nearly white; but, on account of the minuteness of the parts, the structure can hardly be seen without a glass. On fixing the eye on a stripe, it will be found to vary its colour from shining white to dull chesnut, according as the light is reflected from the fibres or from the sections of the medullary plates.

A third source of variety is in the *spongy* or *tubular* portion of the annual layers of wood. This substance possesses in general hardly any lustre; and the sections of the tubes, which make their appearance when the wood is cut up for use, vary greatly in different species, thus creating considerable influence on the ultimate effect, sometimes favourable, but in other cases the reverse. In the wood of the oak, the ash, the walnut, and the cedar, this part of the structure is very conspicuous, and not in general considered an ornament. In mahogany the tubes are smaller, and form by no means so conspicuous a feature in the appearance of the wood. In the lime, the pear-tree, the beech, the birch, the lignum-vitæ, the bird's-eye maple, the plane, tulip-wood, Coromandel-wood, and satin-wood, the tubes are so small as hardly to be visible to the naked eye.

Another circumstance affecting the general appearance of the wood is the contrast or similarity between one annual layer and another. Mr. Aikin illustrates this by saying, that if the circumstances which affect the deposition of wood acted with perfect uniformity, a cross-section of the trunk of a tree would exhibit a number of perfectly concentric circular rings. This however never occurs, more or less of irregularity always being exhibited in the arrangement of these layers. This irregularity is in itself a source of beauty, and is capable of being indefinitely varied by making the section more or less oblique to the axis of the tree. An alternation of colour frequently accompanies these concentric rings; and when the colours are lively, well defined, and well contrasted, their effect is very agreeable; of these many remarkable specimens are met with in yew, king-wood, tulip-wood, Amboyna-wood, partridge-wood, and lignum-vitæ. This distribution of colour passes into the striped, the veined, and the mottled, according to the nature of the wood and the direction in which it is cut. In Coromandel-wood the harmonious tone of the colours, passing from brownish white to rich chocolate, and the broad masses in which they are arranged, give to the wood much the appearance of brecciated marble.

As a fifth source of variety may be mentioned *eyes*, *zoned spots*, and *curls*, which, though in general too small to add to the beauty of large articles of furniture, are productive of considerable beauty in work-boxes and other fancy articles. Bird's-eye maple, Amboyna-wood, pollard-oak, and curdled elm (formed of the knobby tubercles which constitute the root and trunk of the common elm) afford many pleasing specimens of these diversified surfaces.

Lastly, the general colour may be noted:—of mahogany and rosewood we need say nothing, they are so well known; king-wood and zebra-wood, both from Brazil, are generally of rich yellowish brown, more or less varied by other tints; giaca, crocus-wood, snake-wood, and sandal-wood, are among those which partake more or less of a brown colour; satin-wood, brought from India and the West Indies, and fustic, are two varieties in which yellow is the prevailing colour; the cam-wood, the barr-wood, the red sanders, the tulip-wood, the beef-wood, are among the foreign varieties of reddish-coloured woods. The varieties of British wood kept unpainted on account of their beauty of appearance are not great in number; the yew, the elm, the pollard-oak, and the walnut are perhaps the principal.

In cutting up any of these kinds of wood into veneers a circular saw is generally employed; the saw being attached to an axis which maintains a constant general position, while the log is driven up in contact with it by means of steam-machinery. This is the customary but not the only plan adopted.

Mr. Barlow describes a remarkable mode of cutting veneers, as adopted in Russia. The operation is begun by placing the log on a square axle, and turning it to a circular or cylindrical form while in rapid rotation. The blade of a plane of highly tempered steel, rather longer than the cylindrical log of wood, is fixed at the extremity of a frame six or seven feet long, in such a manner as to exert a constant pressure upon the cylinder, and pare off a sheet of equable thickness, which folds upon another cylinder like a roll of linen. The frame is so regulated as to depress the plane in proportion as the cylinder becomes pared away towards the centre. This machine is said to cut the most valuable woods without any waste, and with great rapidity; while the thinness to which the veneer is cut is so extraordinary, that it has been used for the covering of books, and other purposes where leather and paper are usually employed. The veneer thus produced is, in fact, nothing more nor less than a shaving, but one of which the thickness is uniform and equal.

It is said that one hundred feet in length of veneer may be cut by this machine in three minutes.

Whatever be the kind of furniture about to be made, the wood employed is in one of these three states—logs, planks, or veneers, all of various thickness according to circumstances. Perhaps the best way to elucidate the processes is to follow the manufacturing history of some one article, such as a mahogany table, from first to last; treating of the principal departments into which such an occupation naturally separates itself.

The first thing to be done is to form the framework, which is to be supported by the legs, and which is in its turn to support the top of the table. This framework may be considered in the light of neat carpenter's or joiner's work, so far as joints, &c. are concerned. The planks which are to form it are selected of the proper thickness, and sawed to the proper width. This operation of sawing is not so easy as lookers-on are apt to imagine. The plank is laid across one or two sawing-stools, and the saw penetrates it nearly in a perpendicular direction; but if the latter be held too upright, it is liable to tear away splinters from the under side of the wood; and if the blade of the saw be not kept rigorously in the same plane, it will be worked with great difficulty, and the wood will be cut in a crooked direction. The saw used for cutting or 'ripping' a plank into narrower pieces has no frame or strengthener at the back edge, since this would impede the progress of the saw through the wood. The cross-cutting of the pieces to the requisite lengths is a less difficult task, on account of each cut being only a few inches in length.

The next operation after the cutting of the planks is that of planing or smoothing the various surfaces. This is sometimes done when the plank is in the whole or uncut state; but whether before or after the sawing, the mode of producing a smooth surface is pretty much the same. There are planes of different sizes employed, according to the roughness of the wood. The first is a long coarse plane called the jack-plane; and with this the first roughness of the wood is taken off. It is succeeded by another plane, rather broader and heavier, called the trying-plane: this has a very smooth and true edge, and brings the surface of the wood to a true level. But it is likely to happen that neither of these planes is capable of reaching any little depression there may be in the surface of the wood, and that the latter accordingly remains rough. In such a case a third plane is used, called the smoothing-plane; it is much smaller than the others, and is particularly useful where the wood is hard, or where the pieces to be planed are of small size. The plank or piece of wood, while being planed, is kept firmly down upon the bench by means of a stop or fastening at the end; and while the edge is being planed, the plank is fixed edge uppermost in a kind of long vice attached to the front of the workman's bench. During the progress of the planing, squares are occasionally used, to determine the true level of the surface, the rectangular position of the edges, &c. These squares are of different kinds and sizes, according to circumstances; but there are generally two arms or branches fixed at right angles to each other.

The modes of sawing and planing do not differ much for the different parts of a piece of furniture. Whether we are speaking of the top or bed of a table, the framework, or the drawers (if it have any), the various pieces are cut or planed nearly in a similar manner, the chief difference being that the harder wood may be, the sharper and better must be the tools employed to work upon it. If, however, any portion of the woodwork be curved or arched for the sake of ornament, the sawing then requires more care, since the saw has to be carried round in the direction of the curve, instead of following a straight course.

One distinction between the work of the carpenter and that of the cabinet-maker is, that the latter uses very few nails to secure the different portions of his work; while the former uses a great number. Numerous as are the pieces forming a mahogany table, there is scarcely an iron nail to be found throughout it. One reason for this is, that the head of a nail would present an unsightly appearance in a mahogany article of furniture; but besides this, peculiar joints are made, which, with the aid of glue, render the use of nails quite unnecessary. A great variety of joints are known to the cabinet-maker, each of which is useful under different circumstances. One is called mitreing, and is similar to that by which the corners of picture-frames are joined. Where two pieces of wood are to be joined at right angles to each other, if the ends be cut at an angle of 45°, and then fastened together, the right angle is produced. This is called mitreing, and is thus effected:—the pieces of wood are placed in or close to a mitre-box, which is a contrivance for guiding the saw exactly at the required angle, so that the ends of the pieces of wood to be joined may be cut off at that angle (45°): the mitre-box is then exchanged for a shooting-board, which is merely a guide for a large plane, by which the angular end of the piece of wood is planed quite smooth without altering the angle. The pieces thus prepared, when glued together, would constitute a rectangular frame. Another kind of joint, still more frequently used by the cabinet-maker, is that called dovetailing. This is a curious kind of interlacing of the ends of one piece of wood with those of another; the end of one piece being cut into a series of notches or holes, and the end of the other piece, to be joined to the first, being cut so that projecting pins shall be left to fit into those notches. Each piece of wood is fixed endwise in a vice, and the shapes and sizes of the notches and pins marked in pencil. By the united aid of a small saw and a sharp chisel, little pieces are cut from the two ends of each piece of wood, in a somewhat battlemented manner, and with such uniformity, that the pins of one piece shall be exactly the same size and shape as the notches in the other. Sometimes this dovetailing is done in such a peculiar manner that nothing of it appears externally. As to the term dove-tail, it appears to have arisen from a fancied resemblance between the pins and the shape of a dove's tail, though this resemblance is certainly somewhat forced.

It is by the last-mentioned kind of joint that the frame of a table is generally put together, glue being used to assist in retaining the joints. Of glue we may merely remark that it is produced from the hoofs of oxen, and other coarse animal substances containing gelatinous matter, which are boiled in water to the consistence of a stiff jelly: this, whatever be the nature of the woodwork on which it is employed, is laid on with a brush while quite warm; and if the joint be well made, it will become, when the glue has hardened, nearly as firm as the solid wood itself. In the frame of a table, after the dovetailing and glueing of the joint are completed, there are generally blocks of wood placed in the angles and corners, to assist in keeping the framework together; and if the table be large, there are cross-pieces, or strengtheners, placed from side to side of the frame.

We suppose our table to have one or two drawers, of which the front will be made either of solid mahogany or veneered upon deal, and the bottom, back, and sides will be either of mahogany or deal, according to the excellence and price of the article to be produced. In either case the drawer itself is made nearly in the same way; it is in fact a neat kind of box, of which the front only is required to have anything like a handsome appearance. The corners or joints of a drawer are usually dovetailed, and strengthened by small blocks of wood afterwards glued in. The thickness of the wood required for the drawer will depend usually on its size; but the front, which is the only part that meets the eye when the drawer is closed, is usually stronger and thicker than the other parts, in order to afford sufficient space for the handle, key-hole, lock, &c. The framework of the table must of course be so shaped as to leave a neat and well-fitting groove in which the drawer may slide. It is not necessary for the drawer to rest or slide on a bottom of wood; it is sufficient that a ledge or groove exists at the side of the drawer which shall work in a convenient way in the side of the frame.

The legs of the table, if they are to be square, or nearly square, can be prepared by the cabinet-maker out of a thick plank of mahogany by the aid of his saws and planes; but as it is usual for a mahogany table to have turned legs, we will assume such to be the case in the present instance. In such a case the cabinet-maker has very little to do with the legs until the turner has performed his part, for it is very seldom that a cabinet-maker is at the same time a turner. The art of turning is familiar enough to those who have witnessed it; but to those who have not, it is difficult to convey a description in writing. The piece of wood to be turned is first brought by the saw into something approaching to the proper dimensions, and then fixed upon an instrument called a lathe, in such a manner that a rapid rotatory motion may be given to it by the pressure of the foot of the workman on a treadle beneath. The humble itinerant knife-grinder's machinery will show us how a rotatory motion is produced by such means. While the piece of wood is rotating, the turner places a sharp chisel or gouge against its surface, so as to cut away the wood as fast as new portions are presented to its edge by the rotation. In sawing, planing, or carving, the cutting-tool moves onwards, while the wood is stationary; but in turning the tool is nearly stationary, and the wood turns round to meet its edge. Considerable dexterity is required in preventing the cutting-tool from digging too deeply into the wood, or from varying its distance from the axis of the piece of wood. As a circular leg for a piece of furniture is almost always more or less ornamented with mouldings, curves, &c., these mouldings are produced by using cutting-tools of different sizes and shapes, and by cutting deeper towards the axis of the wood in some places than in others. The varieties of pattern that may thus be produced are of course inter minable, and great scope is left for the workman to display his taste. Where the table, such as we now suppose it to be, is one standing on four legs, the turning is in general not so ornamental as in those large central tables where there is one massive leg or pillar in the middle, supported by a kind of plinth beneath; in the latter case there is generally some carving introduced in addition to the turning, which is the work of another kind of workman; but this we need not consider here. The mahogany employed for the leg of the table is inferior in quality to that which is cut up into veneers, but superior to that employed for parts of the furniture which are but little seen; and as the legs are not veneered, the surface of the wood of which they are made must be brought to an appearance, as to smoothness, &c., fit to meet the eye.

The upper end of each leg is generally left square, and either fastened to the framework of the table in some secure manner, or else the pieces which form the frame are fixed to the legs instead of being framed to each other end to end. Where the parts are united in the last-mentioned manner, the joint is generally that which is called tenon and mortise, a kind of joint which is very much used in carpentry, but not so extensively in cabinet-making; dovetailing is usually employed when two pieces of wood are joined end to end; but tenon and mortise is the more frequent joint when the end of one piece of wood is fixed to the side of another: the latter is the case with respect to the legs and frame of a table. The tenon-and-mortise joint consists simply in this:—a hole is chiselled completely or partially through the thicker piece of wood (in this instance, the leg): the height and width of this hole are rather less than the width and thickness of the smaller piece; and the end of the latter is cut away until it exactly fits the hole. When the two pieces are fixed together, the mode of joining can scarcely be seen, and yet possesses considerable strength. The mode of fixing the legs to the framework must depend principally on the form of the table, and whether or not there is a drawer to it; and more or fewer strengthening blocks will be required according to the size of the table.

Our mahogany table still wants that without which it would not be recognised as a table at all, that is, the flat top: for this the workman must reserve his best piece of mahogany, and must exercise his best skill, since it is that part which comes most frequently under the eye.

Two different modes of proceeding are adopted, according as the top is veneered or not. In the latter case a good, sound, and handsome piece of wood, probably about an inch in thickness, is selected; and as mahogany planks are frequently to be met with two or three feet wide, it is very probable that no glueing will be necessary. The wood is prepared with more care than if it were deal, both on account of the superior appearance required, and of the difficulties which the grain of the wood presents. In planing a piece of deal, if attention is not paid to the direction of the grain, the plane digs up the wood in pieces, instead of taking off a shaving; but on reversing the position of the piece of wood on the bench, all is set right. In planing mahogany, however, this reversing of the wood is not sufficient, on account of the exceeding crookedness or "crossness" of the grain;

and in order to prevent the cutting of the surface in a ragged manner, the iron of the plane is confined by another iron in such a manner as to be able to take off only a very thin shaving from the surface. The surface is planed all over with considerable care, and for a much longer time than if the wood were deal; and even after the plane has been sufficiently used, the surface of the wood is well scraped with a smooth but somewhat blunt steel edge.

Where the top of a table is not veneered, and even sometimes where it is, it is customary to finish the edge with a reeded, hollow, or oval moulding. For everything of this kind, the cabinet-maker, as well as the joiner, is well provided with planes: the iron of each plane is not flat or straight-edged, as in those for smoothing, but is cut into the form requisite for producing the moulding, and is fixed in a block or frame whose face has nearly the same figure. The board whose edge is to have a moulding of any sort worked upon it, whether it be the top of a table or anything else, is fixed firmly with the edge uppermost, and then planed to the proper form.

But a veneered table-top is that of which the making is most difficult. As veneering is a plan adopted to save a portion of the expense which would be incurred by using solid mahogany, it is seldom that the veneering is done on mahogany; but a cheaper wood, such as deal, is used for the ground, since it will not meet the eye when the furniture is complete.

As deals are not wide enough to form the top of a table, two or more of them must be glued side by side, to make the necessary width; and this requires us to speak of other kinds of joints than those previously mentioned. We have said that when two pieces of wood are joined end to end, the dove-tailed joint is very much used; and that when the end of one piece is joined to the side of another, the tenon-and-mortise joint is more employed. Now in the present instance the joint is different from either of those; for two pieces of wood are united side by side, so that the ends of the fibres do not form part of the joint. In this latter case, if the wood is well seasoned, the edges may be planed at right angles to the surfaces, and then glued together; for if the two edges are brought together truly parallel, the glueing will produce a very firm and excellent joint. For some purposes it is necessary to plough a groove in the edge of one board, and leave a corresponding projection in the edge of the other, so that the two boards in some respects lap over each other. In other instances a groove, or rebate, is made in the edge of one piece of wood towards the upper surface, and in the edge of the other towards the lower surface; so that the projecting part of one piece shall fit into the hollow or grove of the other. We believe, however, that the common and simple joint is that most frequently employed for a broad slab or surface afterwards to be veneered; and the following plan is sometimes adopted, to prevent the wood from warping, &c.:—those deals are selected which are most free from knots, and are slit down into pieces four inches or four and a half inches wide; these are glued up, an edge which had been nearest the heart of the tree being joined to an outside edge; when the glueings are dry, the board is cut up again into slips, midway between the former joints, and rejoined, a change being made in the order of placing the pieces. By this means the whole top of the table consists of pieces only about two inches wide, glued together so as to lessen as much as possible the liability to warping.

Let us suppose then, that the piece which is to form the top of the table is glued up to its proper size, and ready for veneering; we proceed to speak of this important process. We have already described the means by which the veneers are cut from the log of mahogany; and from the description given it will easily be understood that both surfaces of each sheet of veneer are left rough by the action of the saw. The cabinet-maker buys the veneer in this rough state, and he must alter the nature of the surface before he can venture to glue it on the work. He cuts a piece of veneer a little larger than the top of the table, to allow for waste, &c., and lays it flat on his bench. He then takes a veneering-plane, and works regularly over the whole surface of the veneer in the direction of the grain: this veneering-plane is of small size, and the iron belonging to it, instead of being fine and smooth like that of other planes, is jagged with a number of notches, like the teeth of a very fine saw. With this plane the veneer is worked until all the saw-marks are obliterated, and replaced by regular channels, or rather scratches, along the direction of the grain; and the surface on which the veneer is to be glued is scratched with the plane in like manner; the object of these scratches, or this symmetrical roughness, if we may use such a term, is to enable the glue to take a firmer hold.

The glue for veneering should be sufficiently fluid to flow easily from the brush, and the wood on which it is to be laid must be well warmed before a fire. When all is ready, the glue is laid on with a brush, quickly and in plentiful quantity. The piece of veneer is then taken by two persons, laid on the slab of deal, and rubbed backwards and forwards to press the glue into all the little indentations in both surfaces of the wood; it soon becomes so adhesive as to be no longer capable of being moved to and fro, and is then left in its place. The slight pressure it has hitherto undergone has not been sufficient to make the veneer adhere in every part to the deal; and there are many spots where the veneer swells up, in consequence of accumulations of glue beneath. To level these protuberances is a point of much importance, and is effected thus :—a piece of wood about three inches square and an inch thick has a straight strip of iron-plate fixed to one edge, and is called a veneering-hammer; the workman takes hold of it by a handle projecting from the right side, places the iron edge close to the veneer, and, with his left hand resting on the block to increase the pressure, works regularly all over the veneered surface, squeezing out the superfluous glue from every spot where it may happen to have lodged too abundantly. The pressure or rubbing begins at the centre, and proceeds thence towards the edges, where the glue is forced out; from time to time the workman strikes the veneer in various parts; if the sound returned is distinct and solid, it is known that the veneer adheres closely to the deal; but if it is hollow or dull, he infers that either glue or air prevents the contact of the surfaces: in the latter case a greater degree of pressing or rubbing is necessary. Two men are generally engaged at this work, in order to get the veneer firmly pressed down before the glue becomes too cold. As the outer edges are very likely not to adhere closely, they are kept down either by the pressure of heavy weights or by wooden screws often used by the cabinet-maker; these screws consist of two pieces of wood, or clamps, which are brought into greater or less proximity by means of wooden screws; they are placed so that the veneered surface shall be grasped between the two clamps, and retained there till the glue is cold. When the glue is cold, the veneer is tried all over again with a hammer, in order to discover, by the sound, whether there are any hollow places beneath; if there are such, they are remedied in a singular manner: a hot iron is laid on the defective part, which thus becomes hot through, and re-melts the glue beneath; a small portion of the veneer is also heated from that spot to the nearest edge, and by means of the sort of channel thus produced the glue which had caused the defect is squeezed out towards the edge. This is the only means known for remedying a defect which would spoil the appearance of the table if allowed to remain.

Whatever other part of the table, such as the front of the drawer, or any part presenting a tolerably plain surface, may be veneered, the mode of effecting it is nearly identical with that described above; if the surface is curved, an additional degree of care is required to make the veneer bend round the curvature and adhere to it, but in other respects the process is similar. Generally speaking, where a table is provided with flaps, it is customary to make the flaps of solid mahogany,—indeed the whole top of the table; because there are so many sharp edges exposed when the flaps are down, that a veneered surface would be very liable to be split and broken, on account of the difficulty of making veneers adhere at the extreme edges.

The table-top, whether of solid mahogany or veneered, is usually fixed on the framework by screws from beneath; these screws pass obliquely upwards through the framework, and penetrate into the top of the table sufficiently to ensure a firm hold, but without appearing at the upper surface. In a flapped table the flaps are connected with the central part of the bed by a joint, which, as it is frequently in sight, is finished with much neatness; the adjoining edges of the wood, and the hinges which form the connection, are prepared with much care and neatness also.

We have said nothing yet of polishing: our table still retains the appearance which the many processes to which it has been subjected have given to it: the veneered table is, indeed, in a very unsightly condition; scratched, rubbed, and with ragged edges; the finishing and polishing are therefore important matters. The surface of the veneer is, when quite dry, worked carefully over with a scraper, which consists of a flat square piece of steel about three inches long, with both edges very straight and smooth; these instruments are generally made out of old saw-blades. With this tool the veneer is scraped until all the scratches produced by the veneering-plane are removed from the surface, and the whole rendered level and smooth. This smoothing is further assisted by the use of glass-paper or sand-paper, which is well rubbed over every part of the veneer; the sand-paper is wrapped round a block of cork or of wood, by way of handle, and different degrees of fineness are used, the coarsest first. This process, to a smaller extent, is necessary for solid mahogany; but as it has not been scratched by the veneering-plane, a less degree of smoothing will suffice.

The table is now ready for polishing, a process which has, of late years, been done in a very beautiful manner. In old dark-looking family furniture, the polish, which used to form the pride of those who assisted in preserving it, was produced by frequent and long-continued rubbing alone; furniture-oil, which is in fact coloured linseed oil, will produce a good polish, but only after long repeated applications. Another mode long adopted was that of dissolving bees-wax in turpentine, and rubbing it on the wood with a piece of cloth; this produces a polish sooner than oil, but is in many respects inferior to it. The most perfect of all these contrivances is the use of what is called French polish; this is a varnish which is rubbed into the pores of the wood instead of being laid on with a varnish-brush. There are numerous receipts for making French polish, but nearly all of them consist of rectified spirit of wine, gum shell-lac, gum seed-lac, and Venice turpentine; or three out of these four.

Supposing the table to be ready for the polisher, the surface is wetted with oil, which is allowed to remain on for some time to deepen the colour, and is then carefully wiped dry. A piece of flannel is then wrapped up into a hard close coil; and the surface of this flannel is slightly wetted first with a little French polish and then with a little oil; a piece of clean linen is stretched over the coil to prevent any little impurities from the polish from getting on the furniture, and the coil is then rubbed gently backwards and forwards over the whole surface of the mahogany. The oil is no further useful than in facilitating the rubbing of the polish into the pores of the wood; if it is used in too great quantity, the surface of the wood becomes dull in consequence. When the small amount of polish has worked through the linen cloth and spread itself on the mahogany, the linen is removed, a fresh touch of polish and of oil given to the flannel coil, and the process repeated as before. This is continued in the same manner for a long period of time, as the portion of polish actually laid on at each application is a film of the most extreme thinness; indeed polishing is one of those manual employments of which the charge is made almost wholly for the workman's time, since the value of the material used is extremely small.

The polishing of any surface of an ornamental description, or any spots depressed below the common surface, is rather difficult, and requires a good deal of care; if the polish is allowed to remain in a pool, a fine surface cannot be produced; and if no polish at all reaches it, the defect is of course still greater. Sometimes the polish, on account of ornament, &c., cannot be rubbed at all; and it is therefore laid on in those parts merely as a varnish, by means of a brush. We may here remark that the philosophy of the action of a spirit varnish is this:—the solid matter held in solution by the spirit closely adheres to the polished body, while the spirit evaporates; when all has evaporated, the minutely divided gums or resins forming the solid matter of the varnish become firmly united in a dry state, forming a glossy envelope to the wood.

Beautiful as French polish appears to the eye, it is not invariably useful, since it is incapable of bearing heat without injury; it is for this reason that dining-tables are generally left without any other polish than that which furniture-oil may gradually impart to them; the hot dishes which these tables so often bear would crack and blister French polish, if that were employed.

THE END.

LONDON: WILLIAM CLOWES AND SONS, STAMFORD STREET.

# BRITISH MANUFACTURES.

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## SERIES V.

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BY GEORGE DODD.

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# BRITISH MANUFACTURES.

## SERIES V.

### INTRODUCTION.

The manufactures connected with the daily wants of life are so varied, that it would be difficult to determine where they begin or where they end. Indeed it must always remain a matter of individual opinion at what point to draw the line between absolute wants and mere conveniences or luxuries. There is, however, no particular need for determining this: we may view the principles and details of a manufacture with reference to the ingenuity displayed in the processes, without of necessity following the manufactured product through its subsequent history.

The production of *Food*, if regarded as a manufacture at all, must obviously be placed in the first rank as respects its urgency. But it is curious to observe how little of manufacture, properly so called, is involved in it. The rearing of the animals which supply one large department of our food, and the growth of the plants that supply the remainder, are grand operations which it would be a misuse of terms to rank among manufactures; although they certainly require a large measure of industry and of mechanical ingenuity to facilitate their development. Agriculture might, in one sense, be deemed a manufacture; and so might dairy husbandry: since the object of both is so to modify natural products as to fit them to be used as food; but such an acceptation of these terms departs too much from common usage to be desirable.

It is observable that the preparation of liquid food involves manufacturing arrangements of a much larger kind than that of solid food. When the grazier has reared an ox or a sheep, the culinary art is pretty nearly the only "manufacture" that the flesh is doomed to undergo before being consumed; and when the farmer has harvested his wheat, the miller and the baker are nearly the only manufacturers whose services are available in its subsequent preparation. But with drinks this is not the case: the manufacturing operations through which grains of corn pass, in order to procure from them the various kinds of fermented drinks, are complex and extensive, involving mechanical and chemical arrangements of considerable importance. There are one or two other manufactures of some magnitude, which occupy a sort of middle place between the two classes above alluded to. For instance, *Sugar*, as a zest or addition to both classes of food, is a product requiring large mechanical arrangements for its preparation. *Tobacco*, again, is a product to which much manufacturing ingenuity is directed in its progress towards a useable form. How far alcoholic drinks, and malt-liquors, and tobacco, may be deemed worthy of being ranked with the other produce mentioned above, is not a question for discussion here: they will be considered simply in a manufacturing point of view, and must bear censure in other respects as best they may.

In this volume a glance will be taken at the general features in the branches of manufacture here alluded to, and in this respect it may be considered as relating to Food. There will, however, be given, towards the end of the volume, a sketch of two branches of manufacture relating to clothing. A former volume of the series, devoted to 'Textile Manufactures,' takes a review of those very important branches of art relating to woven goods; and a few matters which could not consistently come under notice in that volume will find a place in the present:—for which reason a neutral title has been chosen for it.

# CHAPTER I.

## BREAD; SUBSTITUTES FOR CORN-BREAD; MACHINE-MADE BISCUITS.

THE manufacture of the various kinds of bread involves important chemical processes; for the contents of each little grain of corn require much modification, not only in appearance, but in constitution. In all bread, except biscuits and a few other kinds intended to keep a long time uninjured, the materials are made to undergo a process of "fermentation," by which certain remarkable properties are developed in them. The crushing of the grain, to liberate the meal within the husk, is a mechanical process; but all after this partakes more of a chemical than a mechanical character.

### *Corn-Bread.*

Nutritious grains, from which bread may be made, bear a considerable resemblance one to another, and all are occasionally selected for this purpose; but wheat possesses the most valuable properties. It is for this reason that the term 'wheaten' is applied to the better kind of bread, and commands for it a higher price.

When wheat is brought to the miller, it is generally too moist for grinding, as, instead of becoming a powder, it would simply be crushed, and would thus clog the millstones. The wheat is therefore spread over a floor constructed of tiles full of small holes. A fire is kindled below the tiles, and the heated air ascending through the holes is admitted to the wheat, which is spread in a layer three or four inches deep. The wheat is subjected to the action of this heated air for about three hours and a half, during which time it is frequently turned over and stirred up. The action of the heat removes the moisture from the grains; and when steam ceases to issue from them, they are removed to a loft, where they are left to cool, and to acquire a certain degree of mellowness, without which the resulting flour would be of inferior quality.

The wheat is now to be cleansed. This is effected by means of a wire cylinder called a *separator*, the wires of which are bent into the form of hoops, and are placed so close that when the grain is introduced and the separator whirled round, none but the small ill-conditioned grains and particles of dirt and sand fall through. The small grain is sold to the distiller, for the purpose of making spirit; and the larger grain which remains in the cylinder is reserved for the making of bread.

The grain is next placed in another screen, consisting of a cylinder of sheet-iron punched full of holes from the outside, whereby a sharp burr points inwards from each hole. The corn is agitated in this cylinder for the purpose of removing the rough end of the grain, which is a brownish soft kind of hair. The grain is next put into an oblong box having a wire-gauze bottom: the box is shaken rapidly to and fro; and at the same time certain fans or vanes, which revolve round an axis placed across the box, excite a current of air through the grain, which blows off the adherent dust and bran.

The grain is now carried to the mill, which, properly speaking, consists of two large stones placed one on another; the upper one of which revolves round a central axis, while the lower one remains stationary. The corn is made to pass through a hopper or funnel into a hollow space between the stones, occasioned by the contiguous surfaces of the stones being concave. The upper stone being set in motion, the corn becomes broken up into powder, and is whirled out from between them in the form of meal. As this meal is a mixture of flour and bran, the latter consisting of the husks of the grain, it is necessary to separate them; and for this purpose the meal is placed in a wire cylinder, down the middle of which, and occupying its whole length, is a brush, consisting of a rod from which branch out hairs that touch the wires of the cylinder. The brush being made to rotate, all the flour of the meal is forced through the interstices of the cylinder: the bran, as well as portions of grain not reduced to flour, being retained. The contents of the cylinder are again ground between the millstones, by which an inferior kind of flour is produced: this is again passed through the cylinder, and the residue again ground, by which a still inferior flour is afforded.

By these processes are obtained three kinds of flour, technically called *first*, *seconds*, and *thirds*; and bread varies in its quality according as it is made of one or other of these kinds. French and cottage bread, best and seconds wheaten bread, and brown bread, differ chiefly in the quality of the wheat flour employed in them. Wheaten flour, in its purest state, consists principally of two proximate substances, *starch* or *farina* and *gluten*, the former occupying about two-thirds the weight of the whole. The existence of gluten in flour may be shown in the following manner:—if a little flour be formed into a stiff paste with water, and worked in the hand under cold water frequently renewed, there results a tasteless, tough, elastic, grey substance, capable of stretching and collapsing like India-rubber; this substance is principally *gluten*, and is the ingredient in flour which confers on paste its adhesive quality; it is also the most nutritive portion of flour.

Before tracing the formation of flour into bread, it may be well to notice the difference between *fermented* and *unfermented* bread. The former is that which, previous to the operation of baking, undergoes a process of partial fermentation, by which the properties of the flour are somewhat altered, and the bread is made light and porous. The latter, of which *biscuit* is a familiar example, is made of dough which has not undergone the process of fermentation. If a mass of flour and water be let to stand for some time, a commotion takes place in it—carbonic acid is formed and tries to escape, and in the act of so doing gives a honeycomb or porous texture to the substance: this process is fermentation. As, however, this fermentation goes on too slowly and too unequally for the purposes of the baker, it is hastened in one of two ways—by the application either of *leaven* or of *yeast*. Leaven consists of a portion of a previous batch of dough which has been laid aside and allowed to partially ferment; and when mixed with new dough, it quickens and improves the fermentation. Leaven is also made artificially in two or three different modes. In some places eight ounces of flour are mixed with a quart of warm water; and for two or three successive days, while the mass is fermenting, more flour and water are added, by which enough leaven is produced to ferment a large batch of dough. In some parts of Germany, wheat-bran and hops are boiled in water, and then left to ferment; when this occurs, more bran is thrown in, until the whole becomes a thick mass, which is then rolled up into balls, and preserved as leaven or ferment.

But English 'quartern loaves' are most frequently fermented with *yeast*, a kind of froth which rises to the top of a liquor in the process of brewing, and which is productive of nearly the same effect as leaven.

The flour and yeast, then, being the principal ingredients, the making of bread proceeds as follows:—A small quantity of yeast is mixed with hot water, so that when dissolved it may have the temperature of blood-heat. The salt (of which about two pounds are generally used to a hundred-weight of flour) is now added, and the liquor is thrown into a wooden trough. About one-third of the intended quantity of flour is added to the liquor, and is worked about with the hands, to free it from lumps. The surface of the mixture (which is now called *sponge*) is then pressed flat; a little dry flour is sprinkled over it, and the whole is covered up closely for several hours. During this time fermentation goes on, and the mass of sponge greatly increases in bulk, in consequence of the formation of myriads of minute air-bubbles within it. The sponge is then mixed with a weak solution of salt, slightly warmed in cold weather. The rest of the flour is added, and the whole is worked up into a stiff uniform mass of dough. The kneading is effected in a very uncouth manner by the elbows and fists of the baker; and it is surprising that in an age when machinery is applied to so many purposes, this primitive mode of kneading dough should be still retained. In many parts of the Continent, and in some cases in England, machines have been employed for this purpose. In one of these machines, the dough is put into a square trough in which a cylinder revolves; and as the dough is carried round by the cylinder, it is pressed through a small aperture left between the cylinder and the trough, and becomes by that means perfectly mixed up into a homogeneous mass. In another machine, the dry flour is put into a hollow revolving cylinder, and water is introduced through perforations in the axis on which it revolves: the rotation of the cylinder then mixes the flour and water; and the mass, in each revolution, has to pass through a narrow aperture, and thus becomes kneaded.

When the dough is made, it is allowed to rest covered up for about an hour, during which time it swells, and, when sufficiently spongy, is said to be "proof." It is then weighed into separate parcels, according to the intended size of the loaves; and these parcels, when sprinkled with flour, are ready for the oven. It may be well to remark that the above is only one mode of making corn-bread: many variations of the process occur in different quarters.

A baker's oven is an arched vault floored with smooth fire-tiles, and is generally heated by means of a furnace placed at the side, the flue of which traverses the oven. The batch of bread is not put into the oven until the coals in the furnace burn with but little smoke. The old form of oven was arranged on the plan of kindling a fire in the oven itself, until it was intensely heated; the fuel was then withdrawn, and the floor cleared from the ashes and dust before the loaves were put in; but it was found that a great amount of heat escaped while the oven was being cleared and cleaned, and thus much fuel was wasted.

Two hours is the time generally allowed for the baking of bread in the usual ovens. The evaporation from the dough carries off about one-tenth of its whole weight during the process of baking, and a further portion of the weight is lost after the bread is removed from the oven. The different appearances which the sides of loaves present are owing to the positions in which they are placed in the oven, whether in contact with the heated tiles, exposed to the heated air, or in contact with one another.

In making loaves of an inferior quality, *potatoes* are very frequently used; and if the quantity be small, the bread is said to be improved thereby; but when added in large quantity for fraudulent purposes, which is sometimes the case, the bread is deteriorated. The existence of too large a quantity of potatoes in bread may often be indicated by the bread cracking and crumbling, by its soon turning sour, by adhering to the knife when cut, and by leaving a depression when pressed by the finger. The erroneous impression that *white* bread must necessarily be better than that of a darker tint, and therefore worth a higher price, frequently offers an inducement to the baker to add bleaching ingredients to his bread, in order to produce this effect; for no flour except the very finest will produce white bread. In this instance, the taste of the purchasers is partly to blame for the occasional admixture of bleaching substances in the bread. Alum, ground bones, or whiting, are among the ingredients occasionally employed for this purpose; and the means whereby the employment of them may be detected are said by chemists to be these:—If bread contain whiting or chalk, and if diluted sulphuric acid be poured on it, there will be an effervescence; but there will be no deposit when pearlash is added to the filtered solution. If ground bones be contained in the bread, and diluted muriatic acid be poured on it, effervescence will ensue; and if it be then filtered and pearlash added, a white heavy deposit will be precipitated. If an excess of alum be used (a very small quantity improves the bread), pour boiling water on the bread; let it cool, and then press out the moisture; boil it away to one-third; when cold, filter it through blotting-paper, and add a little muriate of lime to the filtered liquor: if a muddiness now appear, an excess of alum may be suspected. For a similar end, persons sometimes use an excess of salt in their bread, as, by absorbing a great deal of water, it increases the weight of the loaves: when this is the case, the grain of the bread is very rough; and two loaves, on being parted, generally part uneven, one taking away a portion from the other.

French bread, cottage bread, French and English rolls, &c., are formed in a more porous and lighter manner than the larger loaves; and all, except the last mentioned, are made of the finest and whitest flour. Butter and milk are occasionally added to the other ingredients in fancy bread.

### *Substitutes for Corn-Bread.*

The quality of bread met with in the large towns of England is generally wheaten, more or less fine according to the admixture of bran with the pure wheat flour.

In country places, however, as also in foreign lands, many other descriptions of bread are made.

The inquiries of practical chemists into the comparative nutritive qualities of different kinds of grain have shown that wheat possesses the largest proportion of nutritive matter, but that other kinds are also capable of forming very wholesome bread. Household bread and brown bread, though deemed of inferior quality to wheaten, are still made from wheat flour mixed more or less with bran. The Scotch peasantry, until a comparatively recent period, ate very little wheaten bread. They used to mix a peck of oatmeal with an ounce of salt, and make it into a stiff dough with water, then form it into flat cakes, and afterwards bake it. These oaten cakes, and a somewhat similar kind made from barley, were the substitutes for leavened or fermented bread.

The Cornish miners eat bread made almost wholly of barley instead of wheat. In some parts of the north, peas-meal mixed with oatmeal has occasionally formed the material of bread. Parmentier, the French chemist, proved that potatoes, turnips, horse-chesnuts, briony-root, and other plants were capable of yielding a meal which might be made into bread more or less wholesome. In some cases he cut potatoes or turnips into slices, dried them thoroughly, pounded them, and then mixed them with grain flour; in other cases, the potatoes or turnips were boiled, mashed, and in that state mixed with the flour. A large portion of the bread used in America is made of one-half maize or Indian corn and one-half barley, with a leaven of wheat. One measure of rice with two of barley afford a wholesome bread, as do equal weights of barley and potato pulp, or equal weights of wheat and rye. Grain of rice, the pith of the sago-tree, the root of the mandioc, are all formed in various ways into bread in Eastern countries.

From these details it appears that many vegetable substances are susceptible of conversion into a material for bread more or less salubrious; and it is an object of prominent importance to increase this list, since it is not in human power to command at all times a plentiful return for the labour which the husbandman bestows on his field of corn. With respect to trees, the woody parts are obviously the most extended and bulky; and it becomes an object of no small interest to inquire whether wood contains any nutritious principles.

There are two circumstances whereby wood is rendered unfit for food; namely, the foreign matters always mixed with woody fibre, and the compact aggregation of the fibre itself. The former of these obstacles may be overcome by rejecting such woods as naturally contain a great quantity of foreign matter, as the fir on account of its resin, and the oak on account of its tannin, and by removing everything that water can dissolve from the woods chosen. The kinds of wood best answering this description are the birch and the beech.

An attempt to render wood alimentary has been made with considerable success by Professor Autenrieth, of Tübingen. He found it necessary to reduce the wood to a state of extremely minute division—not merely into very fine fibres, but to a real powder. The repeated action of the heat of an oven is likewise required, both to fit the wood for being ground, and to produce some internal change which renders it more digestible. The mode of carrying on the successive processes is as follows:—

The wood is first thoroughly stripped of its bark, and then cut transversely into thin slices about an inch in diameter. These slices are beaten to fibres in a pounding-mill, and then mixed with the sawdust which results from the cutting. The woody particles are boiled in a large quantity of water, in order to remove, as far as possible, the harsh and bitter principles it may contain; or else they are subjected for a long time to the action of cold water, by enclosing them in a strong sack, and beating or treading the sack in a rivulet. The wood is next dried by exposure to the sun or to the heat of a fire, and is afterwards ground repeatedly, till it assumes the form of a rough flour.

The wood-flour is then formed into small flat cakes by the addition of water which has been rendered slightly mucilaginous or gummy. Professor Autenrieth employed one ounce of the roots of the common marshmallow, which rendered eighteen quarts of water sufficiently mucilaginous to make four pounds and a half of wood-flour into cakes. The cakes are baked until they are quite dry and of a brownish-yellow colour; after which they are broken up and ground repeatedly, till the flour will pass through a fine bolting-cloth. According to the hardness or softness of the wood must the baking and grinding processes be repeated more or less frequently. When birch is employed, the labour is much shorter than with beech or other woods of a more compact kind.

The flour thus prepared acquires nearly the smell and taste of corn flour, but never presents the same appearance, being never white, but of a yellowish hue. It does not ferment without the addition of some leaven, and in this case sour leaven of corn flour is the best. With this it makes a spongy and perfectly uniform bread, like common brown bread, and, when thoroughly baked, is said to have a better taste than the bread prepared in times of scarcity from bran and husks of corn. The addition of a little wheat flour is recommended to form a wholesome bread in the following manner:—Two pounds of wheat flour and three pounds of sour wheat-leaven are mixed up with a little wood-flour and milk, and allowed to stand for some hours in a moderately warm place to rise or swell. About fifteen pounds of birchwood-flour and an additional quantity of milk are then kneaded in, and the dough is rolled out into thin cakes. These cakes are allowed to stand for some time to swell, and are then well baked in an oven. Thirty-six pounds of bread may be produced from the ingredients mentioned above.

As a proof that wood-flour is both soluble and nutritious, it has been stated that starch is obtained from it in the same way as from wheat flour, which with boiling water forms a thick, tough, tenacious jelly. More decisive proofs have likewise been obtained by experiments on animals. Professor Autenrieth tried its nutritious effects on a young dog. He kept the dog a whole day with only water, and then set before him a gruel of indifferently prepared wood-flour, salt, and water. At first the animal ate very little of it, and in the evening was very weak from having taken so little food. During the night he ate freely of the gruel, and in the morning became lively. He now had as much gruel as he could eat four times a-day, and in the course of a few days appeared perfectly reconciled to his diet. This course was continued for seven days, the dog remaining in health and even appearing to grow.

The Professor next tried the effects of the wood-flour on himself and his family. They used it in the form of gruel, soup, dumplings, and pancakes, all made with as little of any other ingredients as possible; and not only did they suffer no inconvenience from this kind of diet, but they also found it palatable. When formed into bread, as before described, Professor Autenrieth first tried its effects by eating a quarter of a pound of it, with weak coffee, for breakfast. The more bread he ate, the rougher and more unpleasant did it become: his throat became somewhat constringed and his stomach oppressed; so that he felt convinced at the time that its continued use would prove injurious to him. At dinner-time, however, his appetite returned, and he ventured to eat of several kinds of soup made of this flour. Finding no inconvenience from this, he ate another quarter of a pound of bread in the evening, with some milk, and no longer found any repugnance towards it or subsequent oppression. He slept well, and arose in his usual health.

The above may be ranked among the curiosities of cookery, and only connected with the subject of bread-making by showing what is *possible* rather than *desirable*.

In some districts of Norway and Sweden the bark of trees is converted into bread, which, from the bitter and astringent principles generally residing in that part of the tree, is far less palatable than bread made from wood-flour. According to Von Buch, the mode of making bark-bread in Lapland is as follows:—When young and vigorous fir-trees are felled, the tree is stripped of all its bark, and all the outer parts peeled away, except an innermost rind, which is extremely soft and white. This is hung up for several days in the air to dry, and is afterwards baked in an oven, then beaten on wooden blocks, and pounded as finely as possible in wooden vessels. The pounded mass is carried to a mill, and ground into a meal something like that of barley or oats. The meal is mixed up with *hazel*, with threshed-out ears of corn, or with a few moss-seeds, and cakes about an inch in thickness are formed of this composition. "Nature," says Von Buch, "receives with reluctance the bitter and contracting food, and the boors endeavour to disguise the taste of it by washing it down with water; but in the beginning of spring, after having lived on this bread a great part of the winter, they become weak and relaxed, and are incessantly tormented with an oppressive shooting and burning about the chest." The Laplanders of Kemi Lappmark are described as using bark in a still more crude form. During the summer they peel off the innermost bark of the fir, divide it into long strips, and hang these strips in their dwellings for winter store, subsisting meanwhile almost entirely on fish. In winter, when their supply of fish fails, they cut these strips of bark into small pieces, and boil them with water and reindeer tallow for several hours, till in consistency they form a thick kind of broth.

### *Machine-made Biscuits.*

The application of machinery to manufactures is valuable in proportion to the number of articles of *one kind* required to be produced; since if there be no likelihood of a large demand arising for any one article, it is not often that the expense of fitting up machinery is willingly incurred: but let it be an article for which a demand is at all likely to arise, and nothing is too trifling to be considered unworthy of the application of machinery.

Ships' biscuits are now made by machinery; and one of the reasons for this has been that the manual preparation of them was too slow and too costly during the last war. A landsman knows very little of the true value of a biscuit: to him it is a trifle—an occasional apology for a meal; and whether he calls it "Abernethy," "butter," "fancy," or "sponge" biscuit, he deems it nothing but a trifle. With a seaman it is far different: to him biscuit is *bread*—the only bread that he eats for months together. There are many reasons why common loaves of bread could not be used during a long voyage; the principal is, that, containing a fermenting principle, or leaven, they would soon become musty and unfit for food, if made previous to the voyage; while the preparation of them on board ship would be subject to numerous objections, which we need not stop to explain. Biscuits contain no leaven, and being well baked throughout,* they suffer but little change during a long voyage.

The allowance of biscuit to each seaman on board a king's ship is, we believe, about a pound per day (averaging six biscuits to the pound). The supply of a man-of-war for several months is consequently very large; and it often happened during the last war that the difficulty of making biscuit fast enough was so great that at Portsmouth waggon-loads were unpacked in the streets and conveyed on board ships just on the point of leaving the harbour, there not being sufficient time to convey the biscuit from the contractors to the victualling-department in the usual way. Some of the biscuits were baked in the Royal yards, and some contracted for.

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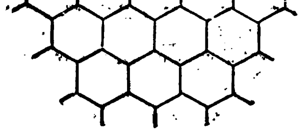
* Biscuits were originally "twice-baked;" hence the French and German names "bis-cuit" and zuie-back."

When ships' biscuits were made by hand, the bakehouse at Gosport contained nine ovens, and to each was attached a gang of five men—the *furner*, the *mate*, the *driver*, the *breakman*, and the *idleman*. The requisite proportions of flour and water were put into a large trough, and the *driver* with his naked arms mixed the whole up together into the form of a dough—a very laborious operation. The dough was then taken from the trough and put on a wooden platform called the *break*. On this platform worked a roller, called the *break-staff*, five or six inches in diameter, and seven feet long. One end of this was loosely attached by a kind of staple to the wall, and the *breakman*, riding or sitting on the other end, worked the roller to and fro over the dough, by an uncouth jumping or shuffling movement. When the dough had become kneaded by this barbarous method into a thin sheet, it was removed to the moulding board, and cut into slips by means of an enormous knife; these slips were then cut into pieces, each large enough for one biscuit, and then worked into a circular form by the hand. As each biscuit was shaped it was handed to a second workman, who stamped the king's mark, the number of the oven, &c., on the biscuit. The biscuit was then *docked*, that is, pierced with holes by an instrument adapted to the purpose. The finishing part of the process was one in which remarkable dexterity was displayed. A man stood before the open door of the oven, having in his hand the handle of a long shovel called a *peel*, the other end of which was lying flat in the oven. Another man took the biscuits as fast as they were formed and stamped, and jerked or threw them into the oven with such undeviating accuracy that they should always fall on the peel: the man with the peel then arranged the biscuits side by side over the whole floor of the oven. Nothing could exceed (in manual labour alone) the regularity with which all this was done: seventy biscuits were thrown into the oven, and regularly arranged in *one minute*, the attention of each man being rigorously directed to his own department; for a delay of a single second on the part of any one man would have disturbed the whole gang. The biscuits do not require many minutes' baking; and as the oven is kept open during the time that it is being filled, the biscuits first thrown in would be overbaked, were not some precaution taken to prevent it. The moulder therefore made those which were to be first thrown into the oven larger than the subsequent ones, and diminished the size by a nice gradation.

The mode in which, since about the year 1833, ships' biscuits have been made by machinery is this:—The meal or flour is conveyed into a hollow cylinder, four or five feet long and about three feet in diameter, and the water, the quantity of which is regulated by a gauge, admitted to it. A shaft, armed with long knives, works rapidly round in the cylinder, with such astonishing effect that, in the short space of two minutes, five hundred-weight of dough is produced, infinitely better made than that mixed by the naked arms of a man. The dough is removed from the cylinder and placed under the breaking-rollers. These latter, which perform the office of *kneading*, are two in number, and weigh fifteen hundred-weight each. They are rolled to and fro over the surface of the dough by means of machinery, and in five minutes the dough is perfectly kneaded. The sheet of dough (about two inches thick), is then cut into pieces half a yard square, which pass under a second set of rollers, by which each piece is extended to the size of six feet by three, and reduced to the proper thickness for biscuits.

This sheet of dough is now to be cut up into biscuits, and no part of the operations is more beautiful than the mode by which this is accomplished. The dough is brought under a stamping or cutting-out press, similar in effect, but not in detail, to that by which circular pieces for coins are cut out of a sheet of metal. A series of sharp knives are so arranged that by one movement they cut, out of a piece of dough a yard square, about sixty *hexagonal* biscuits. The reason for a hexagonal (six-sided) shape is, that not a particle of waste is thereby occasioned, as the sides of the hexagonals accurately fit into those of the adjoining biscuits; whereas circular pieces cut out of a large surface always leave vacant



spaces between. That a flat sheet can be divided into hexagonal pieces without any waste of material, may be seen from the prefixed cut. Each biscuit is stamped with the king's mark, the number of the oven, &c., as well as punctured with holes, by the same movement which cuts it out of the piece of dough.

The hexagonal cutters do not sever the biscuits completely asunder; so that a whole sheet of them can be put into the oven at once on a large peel or shovel adapted for the purpose. About ten or twelve minutes are sufficient to bake them: they are then withdrawn, and broken asunder by the hand.

The corn for the biscuits is purchased at the markets, and cleaned, ground, and dressed at the government mills; in quality it is a mixture of fine flour and middlings, the bran and pollard being removed. The ovens for baking are of wrought-iron, with an area of about a hundred and sixty square feet. About 112 lbs. weight of biscuits are put into the oven at once; this is called a *suit*, and is reduced to about 100 lbs. by the baking. From twelve to sixteen *suits* can be baked in each oven every day, even by the hand process; but it is probable that the machine-made biscuits might be baked with much greater rapidity when required. The men engaged are dressed in clean check shirts, and white linen trowsers, apron, and cap; and every endeavour is made to observe the most scrupulous cleanliness.

A few remarks may here be made on the comparative merits of the hand and the machine processes. If the meal and the water with which the biscuits are made be not thoroughly mixed up, there will be some parts moister than others. Now it was formerly found that the dough was not well mixed by the arms of the workman; the consequence of which was that the dry parts became burnt up, or else that the moist parts acquired a peculiar kind of hardness which the sailors called "flint:" these defects are now removed by the thorough mixing and kneading which the ingredients receive by the machine. 500 lbs. of dough is mixed by the machine in two minutes, and kneaded in four or five minutes; and it need hardly be said how much quicker this is than men's hands could effect it. The biscuits are cut out and stamped sixty at a time, instead of singly, and thrown into the oven a sheet at a time, instead of singly: besides the time thus saved, the biscuits become more equally baked, by the oven being more speedily filled. The nine ovens at Gosport used to employ 45 men to produce about 1500 lbs. of biscuit per hour: 16 men and boys will now produce, by the same number of ovens, 12,000 biscuits per hour.

The comparative expense is thus stated:—Under the old system, wages, and wear and tear of utensils, cost about 1*s.* 6*d.* per cwt. of biscuit: under the new system, the cost is 5*d.* The bakehouses at Deptford, Gosport, and Plymouth could produce seven or eight thousand tons of biscuits annually, at a saving of 12,000*l.* per annum from the cost under the old system. The advantages of machine-made over hand-made biscuits, therefore, are many:—quality, cleanliness, expedition, cheapness, and independence of government contractors.

## CHAPTER II.

### BREWING OF MALT-LIQUORS.

The Porter Breweries of the metropolis are among the most gigantic establishments in the kingdom. There is one of them which occupies an area of eight acres; and all of them reckon their dimensions by acres rather than feet. The arrangements for storing the malt and hops, the supply of water, the boilers for heating the water and boiling the hops, the "backs" and tuns, the vats and casks, the coolers and other vessels—make together an assemblage which never fails to astonish a visitor.

The main object in brewing is to extract from corn a sweetish substance, which, when boiled with water, fermented, and otherwise heated, shall constitute beer or ale. As a means of facilitating this operation, the corn is converted into "malt" before being brought to the brewery; the processes of a "malt-kiln" having for their object to change the nature of the meal within the grain by heat and moisture. The malt is ground by the usual kind of apparatus, and is deposited in a large vessel called a "malt-case," which is situated over a much larger one called the "mash-tun." The malt-case is merely a receptacle to hold sufficient malt for one mashing, until such time as that process is to be conducted, and when this time arrives, valves are opened in the bottom of the malt-case, whereby the malt speedily falls into the 'mash-tun.' This last-named vessel is circular, and is provided with a double bottom, the upper surface of which is pierced with very small holes; the space between the two bottoms is placed in communication with the copper by means of a pipe, and a few large holes, closed with plugs or taps, occur in the lower or true bottom.

This being the arrangement, and the mash-tun being supplied with malt, a proper quantity of water is allowed to flow from a large copper to the space between the two bottoms of the tun; and, percolating upwards through the small holes, it mixes with the malt. The malt and the water are then stirred about by means of a mashing-machine set in rotation by a steam-engine; and after this has continued for a certain length of time, the water, which now contains a large proportion of malt-extract, is allowed to flow from the tun into a square vessel beneath called an 'under-back,' the taps in the bottom being turned on for this purpose, and the holes in the false bottom being too small to allow any of the malt to pass. The liquor thus produced is called 'wort.'

A pump is next brought into requisition, to pump the wort from the 'under-back' into the copper. Here, for the first time, our attention is directed to the hops. Most persons are aware that it is the flower of the hop-plant which goes by the general name of hops, and that this imparts a peculiar bitter, without which beer would not be recognised as such. The hop-flowers are pressed into large canvass bags, and in that state conveyed to the brewery, where they are ranged in large warehouses near the brewhouse till wanted. The bags are conveyed to the brewhouse, thence to the upper part of the copper, and the hops thrown in at a door in the copper called the 'man-hole' (this being the hole at which the men go in to clean the copper after each brewing). The wort and the hops are then boiled together, until the flavour of the latter is sufficiently imparted to the former, the hops being constantly stirred by a rotating machine called a 'rouser.'

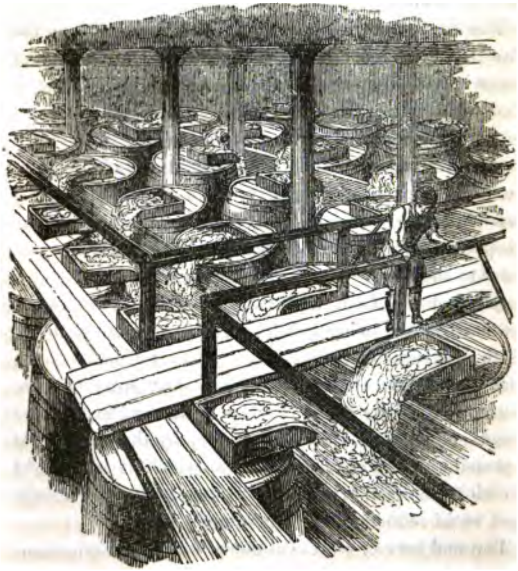
The boiled wort next descends, through a shoot or trunk, from the boiler to a very large square vessel, called a 'hop-back.' As the hops as well as the liquid descend through the shoot, the hop-back is provided with a perforated false bottom, through which the wort flows, leaving the hops above the perforation. The capacity of the hop-back, in some of the large breweries, is as much as four thousand cubic feet; and when filled with boiling wort and hops, the clouds of steam rising from the open surface are, as may easily be imagined, most profuse.

The wort is pumped from the hop-back into 'coolers;' but before we follow it in this process, it may be desirable to say a few more words respecting the brewing. The fermentable matter obtained from the malt is not all extracted at one time; and, therefore, the 'grist' is covered with hot water two or three times, the extract or infusion each time being called a 'mash.' The hops, in like manner, do not lose all their valuable qualities by once boiling, and are, therefore, used again, in fresh portions of boiling wort. In order to convey the drained hops back again to the copper, two plans are adopted. In one, a number of men strip off their upper garments, and get into the hop-back, where they shovel the wet hops, still scalding hot, into a tub or bucket, which is drawn up, wheeled along a stage, and emptied into the coppers: this operation has rather an extraordinary appearance, for the men are enveloped in steam, and are moreover liable to severe injury if any of the hot wet hops touch the upper and unclothed parts of their bodies. In the other method, the hops are raised to the boiler by a contrivance something like the buckets of a dredging-machine; it is called a 'Jacob's ladder,' which dips at the lower end into the hop-back, and empties the hops into the boiler at the top. When the malt and the hops are thoroughly spent, they are thrown into the street, and thence carted away, the one under the name of 'grains,' to be used as food for cattle and swine, and the other as manure.

The first process necessary after draining from the hops is a rapid cooling, which is effected in a manner somewhat striking to a stranger. At the upper part of a lofty building are spacious cooling-floors; the sides of the rooms being open for the free access of air. Each floor is of immense extent, perfectly level and perfectly clean, and in some cases exposes a surface of not less than ten thousand square feet. The floor is divided into compartments by raised ledges a few inches in height, and into the compartments thus formed the hot beer or wort is pumped from the hop-back. The surface of the stratum of beer being so very large in proportion to the depth, the air which is wafted over it from the open sides of the room cools the beer in a short space of time. In some particular states of the weather, when the beer is not cooled with sufficient rapidity by these means, it is passed through a refrigerator, in which it is brought into close connection with cold spring water, thus effecting a rapid reduction of temperature.

The cool beer or wort is allowed to flow into enormous square fermenting vessels, technically called 'squares;' and in these wooden vessels, which sometimes hold fifteen hundred barrels of beer each, the liquid is fermented with yeast for a certain space of time. On ascending a ladder to look into one of these squares, a visitor would remark the singular appearance of the thick masses of yeast covering the surface of the beer, and still more the suffocating fumes of the gas which emanated from it and hovered in a kind of mist over the surface.

In a spacious room called the 'tun-room,' are numerous vessels called 'rounds;' and pipes and cocks are so



Fermenting Vessels.

arranged at the bottom of each as to allow them to be filled with beer from the fermenting squares, at a certain stage in the process. Between the rows of vessels are long troughs, into which the yeast, worked off by the beer through a hole in the top of each vessel, is conducted along a sloping shoot or channel, a mode of arrangement represented in the prefixed cut. This process of working off the yeast is called 'cleansing,' and is important to the future quality of the beer; and although it is a process somewhat dirty and unpleasant in small or domestic breweries, yet in the large establishments all is clean, regular, and orderly; indeed this is not the only proof which such an establishment affords, that the large extent of the operations is the very circumstance which leads to cleanly and orderly arrangement, from the absolute necessity of economising room and time.

Next comes the use of the *vats*, in which the beer is stored when fermented. In one giant establishment, which may be taken as a type of others, these vats are contained in a series of store-rooms, apparently almost interminable. Ranges of buildings, branching out north, south, east, and west, are crammed as full of vats as the circular form of the vessels will permit; some larger than others, but all of such dimensions as to baffle one's common notions of 'great' and 'small.' Sometimes, walking on the earthen floor, we pass immediately under the ranges of vats (for none of them rest on the ground), and might then be said to have a stratum of beer twenty or thirty feet in thickness over our heads; at another, we walk on a platform level with the bottom of the vats; or, by ascending steep ladders, we mount to the top, and obtain a kind of bird's-eye view of these mighty monsters

Without a guide, it would be impossible to tell which way we are trending, through the labyrinth of buildings and lofts, surrounded on all sides by vats. The space occupied as store-rooms may in some measure be judged, when we state that there are one hundred and fifty vats, the average capacity of each of which, large and small together, is upwards of thirty thousand gallons. The town of Heidelberg, in Germany, has gained a sort of celebrity for possessing a tun of vast dimensions, capable of holding seven hundred hogsheads of wine; but there are several vats among those here mentioned, in each of which the Heidelberg tun would have "ample verge and space" to swim about. Prefixed is a sketch of one of these large vats, each of which contains about three thousand barrels, of thirty-six gallons each, and weighs, when full of porter, about five hundred tons.

Next ensues the process of filling the butts with beer. The butts in which the beer is conveyed to the publicans,

and which are so well known in the streets of London, contain one hundred and eight gallons each. An India-rubber hose, similar in form to those which are attached to fire-engines, is connected at one end to a hole in one of the vats, and at the other to the bung-hole of the butt, the latter being placed on the ground with that hole uppermost. Then, by means of a tap or valve governed by a handle, the beer is made to flow from the vat, through the leather hose, to the butt or barrel; and when one butt is in this way filled, the end of the hose is quickly transferred to the hole of a second butt, which is filled in a similar manner. The prefixed cut represents a man engaged at this process of 'drawing-off,' which is effected in cellars on the level of the ground. Some of the store-vats are ranged round these cellars; while those which are at a greater distance are placed in connection with the cellars by pipes and hose.

Most persons perhaps are aware that malt liquors, after fermentation, require a process called 'fining,' to render them more clear and transparent. The liquid with which this is effected is made at the brewery. The 'fining-house' contains large square vessels, and on visiting the building where the manufacture takes place, we found that, small as is the quantity required for each butt of beer, the process is conducted on a considerable scale. The building is at the left hand of the principal entrance to the brewery, and consists of three or four stories or tiers, each filled with square vessels, in which the fining liquid (a solution of isinglass and other analogous substances) is prepared. A very small quantity of this liquid is used to every butt of beer.

In every large brewery there is always kept at hand a vast number of butts and barrels. These are brought empty from the cellars of the publicans, to be repaired and cleansed before again using. One of the most undeviating rules in these establishments,—the golden rule, indeed,—is to observe the greatest cleanliness in every part of the processes; nearly every vessel, large and small, however frequently it may be emptied and filled, and in whatever part of the operations it may be employed, is cleansed after each time of using; according to the nature or condition of the liquid contained in the vessel, so is there a particular mode of cleansing adopted. The butts in which the beer is conveyed from the establishment are especially attended to in this respect. There is a cleansing or steaming house, in which the process is conducted in an ingenious manner. The butts or barrels to be cleansed are ranged, a certain number at a time, round the sides of the building, immediately over a horizontal pipe containing steam from an adjacent boiler; and from this pipe a number of jets or short pipes branch upwards, and pass into the bung-holes of the casks, one to each cask.

But these casks are not only cleansed after every time of using, they are also inspected and measured, and if any leakages or injuries appear, the means of repair are at hand. Adjoining the building where the cleansing is effected is generally a very large cooperage; here may be seen casks, old and new,—iron hoops that had seen hard service, and others destined to replace them,—staves of various shapes and sizes,—and all the tools and working apparatus necessary for a cooperage on a large scale. The sale of beer from some of the large breweries is so enormous as to require the use of sixty or seventy thousand butts and barrels.

It has not formed part of our object to detail the number of hours employed in each part of the brewing processes, nor the particular time of day at which they commence; but the reader will probably suppose that the operations are continued by night as well as by day. The coppers are almost uninterruptedly in use, and relays of workmen succeed each other to attend them. But not only within the brewhouse is activity displayed betimes in the morning; in the open court, long before sleepy London has roused its head, the draymen are busy in hauling up the butts of beer, and placing them on the drays. So many butts are sent out from the establishment every day, and the advantage of conveying them in drays through the metropolis at as early an hour as possible is so great, that by four o'clock in the morning all is bustle and activity; clerks and foremen superintending the operations, and men working the cranes by which the butts are lifted from the cellars to the drays. The form of these drays, of which eighty or a hundred are sometimes employed by one firm, is familiar enough to every Londoner.

The horses for a great brewery are as much attended to as any other part of the arrangement. The stables (where sometimes two hundred horses are kept) exhibit the same cleanliness and order as so many other parts of the establishment present. There is usually a large paved court, around which are the stables and subsidiary offices; here, a dwelling-house and laboratory for the veterinary surgeon, under whose care the health of the valuable stud is placed; there, a blacksmith's shop, provided with the necessary arrangements for shoeing horses; farther on, a harness-maker's shop, where necessary repairs to the harness are effected. But the principal of these buildings are, as may be supposed, the stables. In one establishment, the stables occupy a range nearly three hundred feet in length. A clear passage leads throughout from end to end, the horses being ranged on either side with great regularity; galleries or lofts for provender above them; and an open space for ventilation along the middle of the stables. At one end of the long stable is a building in which the provender is prepared for the horses: a small steam-engine, of five or six horse-power, works machinery by which the oats are bruised or crushed before being given to the horses (a modern practice, productive of much benefit to the health of the animal); and another machine by which the chaff is cut. By an ingenious arrangement, the waste steam from this engine can be directed into a water-trough, whereby any desired temperature may be given to the water which the horses drink.

Many of the great breweries prepare, on the spot, the inscription-boards which relate to "—— & Co.'s Entire;" a phraseology requiring a little explanation. It appears that in by-gone times, beer-retailers were wont to sell a kind of liquor called half and half, that is, half ale and half 'twopenny,' which had to be drawn from two casks. Afterwards a taste was gradually acquired for 'three-threads,' a compound of ale, beer, and twopenny, which the retailer was necessitated to draw from three casks; a process so troublesome, that it led to the brewing of a kind of beer which should combine the qualities of these three sorts, and which, being drawn entirely from one cask, obtained the name of *entire* butt beer. The circumstances under which the necessity arose have long since passed away; but the term is still retained.

The wealth of the great brewing firms is proverbial. It is well known that Dr. Johnson was intimate with Thrale, the predecessor of Barclay and Perkins in the monster brewery at Southwark; and Boswell relates, that "When the sale of Thrale's brewery was going on, Johnson appeared bustling about, with an ink-horn and pen in his button-hole, like an exciseman; and on being asked what he really considered to be the value of the property which was to be disposed of, said, 'We are not here to sell a parcel of boilers and vats, but the potentiality of growing rich beyond the dream of avarice.'"

## CHAPTER III.

### DISTILLATION AND RECTIFYING OF SPIRITS.

THE distilling of spirits or alcoholic liquors from vegetable products is, in a chemical sense, much more remarkable than brewing; since it calls for a much more extended train of operations, comprising in fact brewing as well as distilling.

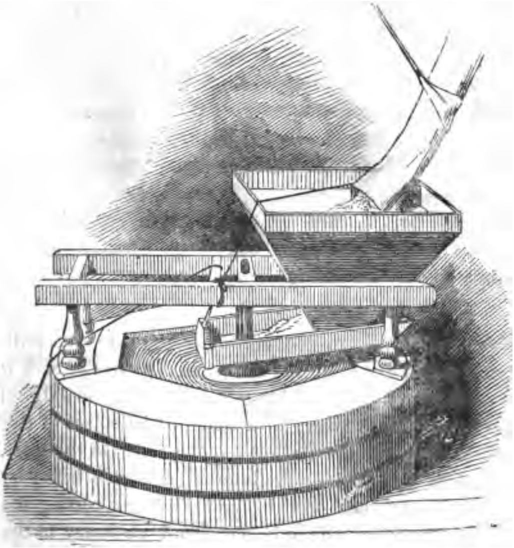
It may be premised, in general terms, that all kinds of grain, such as wheat, rye, barley, oats, &c., whether in the raw or the malted state, as well as the juices of fruits, of the sugar-cane, of potatoes, of beet-root, and of many other vegetable substances, contain certain elements which, by peculiar processes, are capable of being converted into *alcohol* or *spirit.* Distillation always forms one of these operations; but it is preceded by others which vary according to the nature of the ingredients employed. The various liquids known by the names of brandy, rum, whisky, hollands, gin, spirits of wine, cordials, and compounds, all contain the alcoholic principle, developed by the process of distillation. French brandy is produced from wine ; West Indian rum from sugar or molasses; and British spirit, whether called by the name of spirit of wine, British brandy, British rum, whisky, or gin, from corn. In every case the substance which undergoes the process of distillation is a *sweet* liquid ; but the means whereby this sweetness or saccharine quality is brought about differ according to circumstances. The different qualities presented by these various liquids depend partly on the alcoholic strength, partly on the substances whence they are produced, partly on the berries, herbs, and seeds with which they are flavoured, and partly on the mode in which the manufacture is conducted.

The reader will be prepared to understand, then, that the operations of a British distillery relate to the extraction of the alcoholic principle from various kinds of grain; and as this extract is in fact converted into a kind of beer before that change is induced which leads to the production of spirit, it follows that many of the operations of a distillery resemble those of a brewery. The brewer and the distiller alike extract a saccharine substance from grain (principally *malted* in respect to brewing, but more generally *raw* for distilling), by the process of 'mashing;' and alike subject this sweet liquid, called 'worts,' to fermentation. The fermented liquor, modified in a particular way, forms 'beer' at the brewery; whereas in a distillery it obtains the name of 'wash,' and is the liquid which undergoes the subsequent process of distillation.

## *Extracting the Wort.*

The staple ingredient, then, at a distillery, is grain, and this is brought into the establishment to be stored for use. Malt, as before explained, is barley which has undergone, on the premises of the maltster, a process calculated to render it more fitted for the purposes of the brewer than barley or other grain in the raw or unmalted state; but the distiller can employ either raw or malted grain according to circumstances. Malt being much more expensive on account of the duty, than raw grain, the distiller usually employs as little of the former as the nature of the process requires. The proportion now frequently used is one part of malt to ten or twelve of raw grain; the raw grain being varying mixtures of wheat, barley, rye, and oats, according to the state of the market; but more than half of the entire ingredients is generally raw barley.

When about to be ground into meal, the grain is conveyed to a room immediately over the mill-room, and discharged through trap-doors in the floor into channels



Grain Mill.

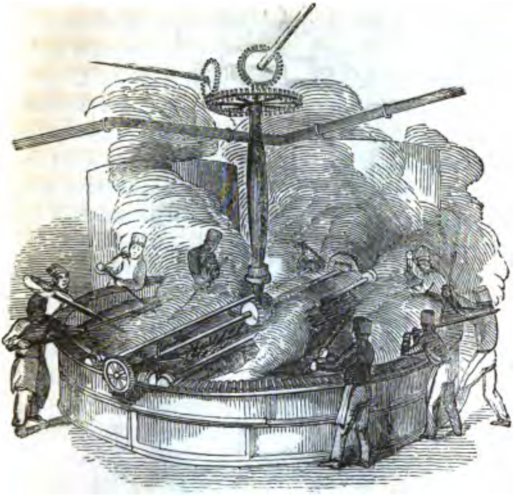
Meal Sacks.

which conduct it to the millstones. There are millstones which grind all the raw grain; while the malt is passed through a 'crushing-mill,' consisting mainly of two rollers placed nearly in contact. The object of this difference is, that the distiller requires to *crush* the malt, instead of *grinding* it; the internal substance being by this means softened or disintegrated without cutting the husk, a precaution which is not found necessary in the case of raw grain. In some distilleries the mill-stones, channels, and bags are arranged as sketched in the two previous cuts. The mill-men fasten sacks to the openings, and thus receive the meal as it descends heated to a temperature of perhaps 100° by the friction of the stones. In the cuts, the first division shows the operation of the millstones in the room above; and the second shows the reception of the ground meal in the room beneath.

The meal, when ground, passes from the mill to the brewhouse, where are large coppers, each provided with a fireplace underneath, and the whole capable of containing several thousand gallons; these are for the purpose of heating the water wherewith the brewing process is effected. The most important vessels in the brewhouse are the 'mash-tuns;' these are cast-iron circular vessels, each provided with a double bottom, one above the other, having a small vacancy between them, and the upper one being pierced with small holes an inch or two apart. From the middle of each tun rises a vertical shaft, set in motion by a steam-engine, and acting upon horizontal arms, studded with spikes or pins on all sides: this apparatus, by rotating both horizontally and vertically, effectually stirs and agitates any ingredients which may be in the tun.

All being ready for the brewing, hot water is admitted to the 'mash-tuns' by pipes leading from the coppers; while ground meal is thrown in at the open top of each tun. The sacks of ground meal are stored in the mill adjoining the brewhouse, and are conveyed into the mash-tuns by various means, according to the arrangements of the distillery. The crushed malt, the ground grain, and the hot water, being admitted into the tuns in the requisite proportions, the rotating stirrer or 'mashing-machine' is put into action, whereby the solid and liquid ingredients are so completely mixed up together that the water is enabled to extract the saccharine elements from the meal. Men are also employed with long-handled instruments to stir the sediment, which might otherwise remain at the bottom; and a scene is then presented such as is shown in the cut. These operations continue for two or three hours, during which a striking chemical change has been going on. Meal consists principally of *gluten* and *starch*; and by the agency of water and a sufficient temperature this starch becomes converted into sugar. The precise explanation of this change involves chemical niceties, into which we need not enter; but it will be sufficient to say, that the water, converted into 'worts' by the process of mashing, acquires a sweet though sickly taste, arising from the starch of the meal having been converted into sugar.

When the 'mashing' has been continued to a certain extent, several pipes are opened, through which the 'worts' are allowed to flow into cast-iron cisterns, or 'under-backs,' in a cellar beneath. The meal is retained by the upper or false bottom of the mash-tun, which thus acts as a sieve or strainer, allowing nothing but liquid to pass through the perforations. The meal does not lose all its saccharine quality by this first mashing: it is therefore 'mashed' a second and a third time, in fresh portions of water; producing 'worts' of less and less strength. As to the number of times that the mashing is repeated, the quantity of water used for a given weight of meal at each mashing, the temperature of the water, and the length of time during which the mashing is continued—these are points on which each individual



Mash Tun.

manufacturer exercises his skill and judgment, and may possibly vary considerably in different establishments. When the saccharine qualities of the meal are as far as possible extracted, the residue, under the name of 'grains,' is carried out to the grain-stage, in the yard of the distillery, thence to be sold as food for cattle.

From the under-backs, the 'worts' are pumped up to the coolers or cooling-floors, occupying the upper portion of some of the buildings of the brewhouse. The floors are sometimes of wood, as described in the last chapter; but occasionally they are covered or paved with cast-iron plates, three or four feet square, and joined edge to edge; raised ledges are placed across the floors at certain dis-

Cooling-floor.

tances, to divide them into compartments; and into the shallow cells or trays thus formed the hot wort is introduced. The whole floor becomes thus covered with a stratum of hot liquor five or six inches deep; which is speedily cooled by the access of air from open windows on all sides of the coolers. This speedy cooling is necessary to prevent the acidification of the sweet wort, a result which has a tendency to follow when the cooling is too slowly effected. Such a mode of cooling is very prevalently adopted in large breweries and distilleries; though in some cases 'refrigerators' are employed, in which the hot wort passes through pipes exposed externally to a current of cold water. It is merely a question of expediency as to which method is employed; for the principle is the same in both cases—viz., the rapid abstraction of heat by a medium colder than the wort itself. In the prefixed cut is represented one of these floors, covered with the hot liquid, and supplied with certain pieces of apparatus whereby a current of cool air is more effectually kept up.

From the coolers the wort descends into the 'fermenting-backs,' or fermenting-squares,' a series of square vessels of enormous dimensions. Here the liquid is exposed to the action of *yeast*, bought for that purpose of the great porter-brewers: the alcoholic fermentation ensues, whereby the sugar, which had been developed from the grain during the process of mashing, becomes converted into alcohol or spirit. This is one of the most delicate of all the operations, whether in a brewery or a distillery, requiring extensive knowledge both of the principles of chemistry and of practical results. The nature of the process may be briefly explained as follows:—The wort, in consequence of containing a considerable amount of saccharine matter in solution, is heavier than water; and the manufacturers express the degree of density by stating how many pounds heavier a barrel of wort is than a barrel of water. Whatever may be the strength of the wort actually obtained in any one mashing, the distiller is confined to certain limits when he transfers the mingled wort to the fermenting-tun; for he is obliged by law to bring the wort to a specific gravity somewhere between 1·050 and 1·090, water being 1·000. This specific gravity becomes gradually lessened in the fermenting-backs, by the gradual conversion of the sugar into alcohol; this latter-named liquid being very much lighter than water. The specific gravity is in fact brought down very near to that of distilled water, and the wort, now denominated 'wash,' may be considered as a mixture of alcohol and water, containing a small quantity of an essential oil, a little saccharine matter, and one or two other substances.

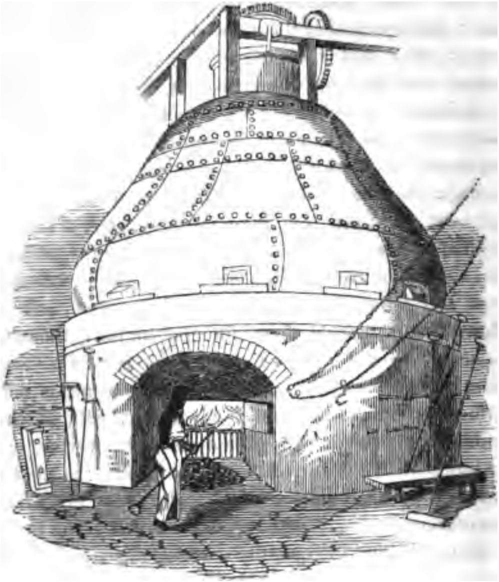
### *Distilling the Spirit.*

We now come to that part of the distiller's operations where it is desirable to speak of the relations between the manufacturer and the Excise. The system of supervision whereby the revenue in spirits is collected is a remarkable instance of Excise machinery; a supervision rendered important by the large revenue annually collected, and by the comparatively small number of establishments from which the payments are made. One single firm pays no less a sum than 300,000*l.* a year to government in duty on the spirits manufactured; and as the duty per gallon is estimated on spirits of one particular degree of strength, the utmost caution is necessary in testing the strength of all the spirits produced, as a guarantee that all the spirit produced shall pay a duty exactly proportionate both to its quantity and its strength. As agents on the part of the government, there are excise-officers almost constantly present at every distillery, day and night. They succeed each other, one or more at a time as may be necessary, after intervals of eight hours; the periods being from six in the morning till two in the afternoon, from thence to ten at night, and from thence to six the next morning. The readers of the public journals will readily call to mind many important investigations relating to these matters.

The act of parliament by which distilleries are now regulated was passed in 1825. By its provisions no distiller is allowed to commence operations till he has procured a licence, which licence is to be renewed annually; nor is he allowed to keep on his premises a still below a certain capacity. The number of stills, chargers, receivers, &c., employed by him is also placed under certain restrictions; and the precise routine is marked out as to the mode in which the liquid shall pass from one vessel to another in the process of distillation. The number of openings in the principal vessels is expressly stated; and the most scrupulous care is taken that nothing shall pass from one vessel to another without flowing through a pipe provided with a cock or valve of which the excise-officer has the key. He is provided with keys whereby he can lock up the furnace-doors, lock up the stills, and in fact exercise a most thorough control over all the operations. In order further to facilitate the supervision of the excise-officers, the brewing and the distilling take place in alternate periods; one portion of time being appropriated to the preparation of 'wash,' or 'fermented wort,' in the brewery, and the next to distillation of spirit from the wash thus produced. On paying a visit to a distillery, therefore, we are sure to find one-half of the operations suspended, according as it may happen to be brewing-time or distilling-time. These complex arrangements arise principally out of the peculiar mode in which the duty is estimated, for not only is the spirit tested as to quantity and strength, during and after the process of distillation, but the specific gravity of the 'wort' and of the 'wash' is taken, the one heavy and the other light, and an assumption is made that a given quantity of spirit will result from a given difference in these two specific gravities. If it happens that the actual quantity of spirit, ascertained after the distillation, differs from the hypothetical quantity arising from the previous calculations of the officer, he gives to the government the "benefit of the doubt," and charges duty on the higher quantity, whichever that may happen to be.

The 'wort,' or sweet liquor arising from the mashing, ferments in the fermenting-backs until its specific gravity is greatly reduced, and its saccharine quality exchanged for one more alcoholic. This liquid, now called 'wash,' is conveyed to a vessel called the 'wash-charger,' as the first step in the distilling process. In order that the intentions of the law may be carried out, which prohibit the simultaneous brewing and distilling in one establishment, the buildings are detached, or at least conveniently divided. The still-house is a large building, occupied by the vessels immediately connected with the distillation; the principal of these vessels being called 'chargers,' 'stills,' and 'receivers;' the first to supply the second, and the third to receive the product. In order to facilitate the supervision of the officer, and to enable him to trace the routine of processes conveniently, the legislature requires that every pipe for the conveyance of water shall be painted *black*, those for the conveyance of 'wort' or 'wash' *red*, those for the product of the first distillation *blue*, and those for the finished spirit *white*.

The 'wash-charger,' into which the wash is conveyed from the fermenting-vessels, is a large iron tank or closed cistern capable of containing about thirty thousand gallons. By the express terms of the law, this vessel must be entirely closed in, and must communicate only with the fermenting-vessel and with the still, so that nothing can flow into it except from the former, and nothing flow out of it except into the latter. In the top or cover is a small hole, about an inch square, into which the officers dip a graduated rod; the object being to determine whether the quantity entering this vessel is the same as had been contained in the fermenting-backs. The officer keeps the key of the cocks or valves leading into and from this vessel, whereby nothing can enter the still until he has unlocked the requisite pipes. The still is a copper vessel, often containing as much as twenty thousand gallons; it is heated by a fire beneath, and is terminated at the top by a cover, which gradually decreases in diameter, and at length joins the 'worm,' of which we shall presently speak; the still is formed of plates of copper firmly riveted, and otherwise so contrived as to be air and water tight.



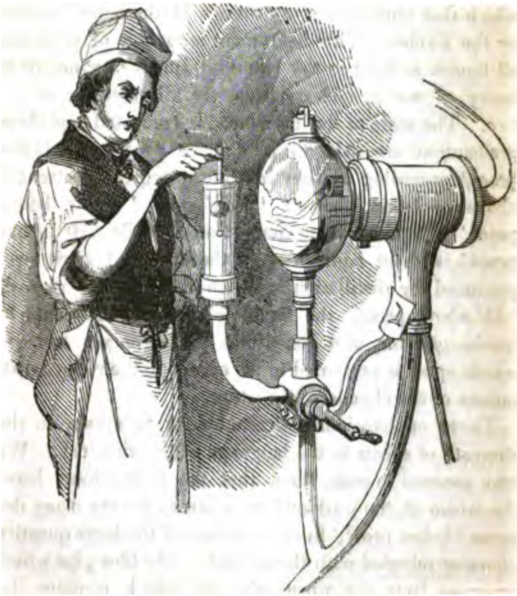
Wash-still.

The 'wash' conveyed into the still consists mainly of alcohol and water, in the proportion (generally) of about six gallons of pure alcohol, or twelve gallons of 'proof spirit,' in a hundred gallons of wash; 'proof spirit' being composed of about equal parts of alcohol and water. Water passes off in the form of vapour at a temperature of 212°; while alcohol does the same at the low temperature of about 180°; and the distiller avails himself of this circumstance to effect a separation of the two liquids. He applies fire to the still, by which the 'wash' is gradually heated; and when the temperature attains 180°, the alcohol begins to vaporise and to ascend to the top of the still. The heat is kept up to some point between the two extremes of 180° and 212°, until all the alcohol has passed off in the state of vapour. But during this process, partly on account of the restrictions imposed by the legislature, and partly through the scientific difficulties of the subject, a considerable quantity of water passes off with the spirit and mingles with it in the form of vapour. When all the alcoholic ingredients are distilled from the wash, the latter, under the name of 'spent wash,' is conveyed from the still to a large open vessel in the yard of the distillery. It is thence carried away in barrels by persons who keep cattle or pigs: the dry food of these animals, being sprinkled with some of the spent wash, acquires a fattening quality, which gives a value to the liquid after it has ceased to possess any to the distiller.

But it may now be asked, what becomes of the alcoholic vapour driven off by the heat of the still? The answer to this question forms the next step in the routine of processes. Near the still is usually the 'worm-tub,' which contains the means for condensing the vapour after it has ascended from the still. This large vessel contains a worm, or coil of copper-pipe, circling round it in a screw-like form from top to bottom. This pipe is not much less than two feet diameter where it enters the worm-tub, but gradually diminishes as it descends, till it leaves the vessel with a diameter of less than two inches. The vacant space of the worm-tub, not occupied by the pipe, is filled up with water, which is constantly flowing in from a water-tank, or 'liquor-back,' at the top of the still-house, an overflow from the top being necessarily provided for. All the vapour which ascends from the still passes into and through this worm or coil of pipe, and in its passage becomes condensed into a liquid by the coldness of the water contained in the worm-tub. Whenever vapour is condensed into liquid, a large amount of latent heat is given out; and as this occurs during the condensation of the vapour in the worm, the water in the worm-tub becomes gradually heated, until at length its temperature would be such as to unfit it for the office of a refrigerator, were there not a constant supply of cold water flowing in, and an equal quantity of heated water flowing out. The rate of change is so regulated as to keep the water in the worm-tub at as low a temperature as possible.

The liquid which flows out at the lower end of the worm is called, in the language of the distillery, 'low-wines:' it is a very weak kind of spirit, containing all the alcohol previously existing in the 'wash,' mingled with a considerable quantity of water. As we shall now have to speak of the *strength* of spirit, it may be desirable to explain the nature of the standard employed by the Excise. Alcohol being of a lower specific gravity than water, a quart or any other quantity of the former would weigh less than an equal quantity of the latter; and any mixture of the two will weigh more or less, according as the water or the alcohol predominates. The Excise adopts as a standard that particular mixture of alcohol and water whose weight bears to that of an equal bulk of distilled water at a medium temperature the ratio of twelve to thirteen: that is, supposing a given bulk of distilled water weighed thirteen ounces, then an equal bulk of standard spirit will weigh twelve ounces. This particular degree of alcoholic strength is called 'proof spirit,' and is the standard to which all other strengths are referred: it consists almost exactly of one-half pure alcohol and one-half water. The strengths of all mixtures of alcohol and water—called by the general name of *spirits*—are ascertained by means of their specific gravity, and this is determined by a hydrometer, of which that kind known as 'Sikes's Hydrometer' is used by the Excise. This instrument is capable of weighing all liquids as light as the strongest spirits of wine, or as heavy as water, and consequently all mixtures of the two. The scale of the instrument is graduated, and these graduations are said to be 'above proof' or 'below proof,' according as they indicate a degree of strength above or below that of 'proof spirit:' '100° below proof' is equivalent to pure water, while '70° above proof' is about equivalent to the strongest spirit ever produced by distillation. When the strength exceeds '43° above proof,' the liquid is known by the name of *spirits of wine*, and constitutes the strongest form in which spirit is presented to us, except in the refined operations of the chemist's laboratory.

These explanations will enable us to allude to the strength of spirits in the language of the distillery. We may proceed to state, then, that the 'low-wines' leave the worm of the wash-still at a strength very many degrees 'below proof,' in consequence of the large quantity of water mingled with the alcohol. The blue pipe which emerges from the worm-tub, and which contains the 'low-wines,' terminates in the curious piece of apparatus represented in the following cut. This apparatus is called the 'worm-safe,' and is intended to afford the means of testing the clearness and strength of the liquid flowing through it. The liquid flows from the end of the pipe into a hollow glass globe receiver, and from thence flows back through a larger pipe concentric with the former. By turning a small handle, a small portion of the liquid is made to pass into an upright cylindrical



glass vessel two or three inches in diameter; and into this cylinder the hydrometer is introduced for measuring the strength of the liquid.

From the worm-safe the low-wines flow into vessels called 'low-wine receivers,' the stronger portion being allowed to flow into one receiver, and the weaker into another. These receivers, like all the other vessels employed in a distillery, are under the control of the excise-officer, who ascertains the quantity and the strength of the low-wines obtained by distillation. From the quantity and the specific gravity can be ascertained the amount of 'proof spirit' contained in the low-wines receiver, and this amount is entered as a check against the operations in other parts of the process.

The 'low-wines,' being much too weak for any of the ordinary purposes of spirit, have to be redistilled, as a means of driving off a considerable proportion of water. This redistillation is effected in other vessels called 'low-wine stills,' or sometimes 'spirit-stills.' But here some degree of complication occurs, of which we can only speak in a general way. Provided all the wash be distilled in the wash-still, and the product collected in the low-wines receivers, the Excise allows the distiller a certain latitude as to the subsequent distillations in the spirit-still. He may redistil over and over again, with a view to improve the quality of his spirit, or to economize ingredients, provided the officer can retain throughout the means of determining that all the spirit obtainable from the wash is ultimately collected in the spirits-receiver; and that none is so collected but what can be thus accounted for. This latitude seems to have been allowed to the distiller partly because a portion of the spirit, redistilled from the low-wines, possesses a disagreeable odour and flavour, which must by some means be removed, and which the distiller may devise the means for removing more effectually if allowed to exercise his judgment in the matter. These impure portions of the spirit, which are called 'feints,' and which derive their peculiar quality principally from a fœtid oil yielded by the husks of the grain, are collected in separate receivers, and are thence reconveyed to the spirit-still to be redistilled. At this point in the proceedings, therefore, each distiller is enabled to exercise his judgment, and apply the results of his experience in the management of his distillery: hence, too, arise the distinctions between strong and weak 'low-wines,' and strong and weak 'feints,' distinctions made to further the views of the distiller. It will be sufficient for our present purpose, however, to state generally, that one distillation in the wash-still converts all the alcoholic portion of the wash into low-wines; and that one distillation in the spirit-still converts the greater part of the low-wines into spirits, the remaining portion requiring a third distillation.

The spirit-receiver is a vessel under the especial supervision of the Excise officers, since the final adjustment of duty is regulated by the quantity and strength of the contents of this receiver. We have before stated that the officer gauges the quantity and specific gravity of the worts in the fermenting-back, and calculates the quantity of proof spirit which ought to be charged for therein, amounting to twelve gallons of proof-spirit from one hundred gallons of wort when the latter has a specific gravity of 1·060. He also gauges the quantity and strength of the proof-spirit in the 'low-wines,' in the feints, and lastly in the finished spirits, with a view to let one method act as a check to the other. The duty is paid on the actual quantity of proof-spirit in the spirit-receiver; but should this prove, on an average of a twelvemonth, to be less than the quantity estimated by the gauge of the worts or wash, the distiller has to pay up the deficiency: if, on the contrary, there is an excess, the Excise retains the benefit of that excess.

From the spirit-receiver, the spirit passes to the store-warehouse, a building in which are ranged large store-vats, numbered (as most of the vessels are required by law to be in a distillery) and inscribed with their liquid capacity. This store-room is provided with the requisite conveniences for filling casks from the store-vats, and for despatching them from the distillery. As spirit does not, like beer, improve by being kept in store for a considerable period, there is no necessity for that vast array of vats which forms such an object of wonder at the great porter-breweries; and as spirit is, bulk for bulk, twelve or fifteen times dearer than porter, a small establishment of barrels, waggons, horses, &c., will be adequate for the business of a large distillery.

### *Rectifying and Compounding.*

Let us now recapitulate the steps through which we have traced the production of spirit. In the first place the grain—consisting of any of the usual varieties, and either raw or malted—is crushed or ground, as a means of allowing hot water to act more readily on the farinaceous ingredient. In the next place this grain is mashed with water till a heavy liquid called 'worts' is extracted. Then the 'worts' are fermented, by which the saccharine principle is converted into alcohol; and lastly, this alcohol is, by repeated distillations, separated from the greater portion of the water with which it had been combined. The result is called 'plain British spirits.' But we have not yet done with it; we have yet to trace it through the hands of another manufacturer.

The liquid so highly valued in science as 'spirit of wine,' the various forms of spirituous liquors known as Hollands, whisky, gin, British brandy, &c., and the cordials known as peppermint, cloves, aniseed, &c., are produced by the *rectifier* from plain spirit purchased by him from the *distiller*. As a means of preventing any surreptitious proceedings in respect of duty, the excise laws prohibit the carrying on of two distilleries, or one distillery and a rectifying establishment, within a quarter of a mile of each other. They also limit the quantity of spirit which the distiller may sell, to a minimum of eighty gallons at one time, with which must be given a 'permit.' As a general rule it may be stated that British spirit (we exclude mention of Scotch and Irish whisky, as, although plain malt-spirit, they are regulated by clauses in the act applying specially to them) is but little known in the form in which it leaves the distillery, since it receives from the hands of the *rectifier* the peculiar properties by which it is rendered familiar. The person's name often attached to spirituous liquors, as a guarantee for the quality, is the name not of the distiller, but of the rectifier. There are only six distilleries in the vicinity of London, and less than a dozen in the whole of England: all the other establishments called by that name being places where the spirit, made from the malt or grain by the distiller, is redistilled, 'rectified,' or purified; and compounded with various vegetable substances to impart flavour.

The raw spirit is sold by the distiller to the rectifier in two different strengths, viz. 25° over-proof, and 11° over-proof, both of which are rigorously fixed by the legislature. The spirit is brought to the rectifier in casks belonging to the distiller, with an excise permit; and an officer visits the rectifying distillery to see that all the spirits received there have paid duty: beyond this point the excise laws do not control the rectifier, except in one or two minor points. Supposing a cask of raw spirits to be conveyed to such an establishment, it is opened, and the contents emptied into a store-vat. From thence the spirit is transferred to stills; some of which are appropriated to the rectifying of gin, while others are for spirit of wine, British brandy, British rum, &c.

Supposing the spirit is to be converted into gin, one of the stills is seven-tenths filled from the store-vats, and steam is admitted to act on the still. The contents ascend in vapour, which is afterwards condensed in the worm-tanks. This distillation is the *rectifying* of the spirit, by which a certain portion of essential oil is removed from it. Then ensues the *compounding*, which is a redistillation with certain herbs, berries, and seeds, in order to impart the particular flavour whereby the liquid is known. Whatever may be the strength of the spirit when it comes into the hands of the rectifier, he reduces it, when in the form of gin, to a strength not greater than 17° under proof.

If spirit of wine is to be made, the crude spirit is pumped into a still whose upper part consists of a vertical cylinder, containing a large number of pipes. The vapour ascending these pipes, and the pipes being surrounded by water at about 180°, the arrangement effects so extensive a separation between the alcoholic and aqueous vapour, that spirit can be obtained as high as 62° over-proof. It must, by law, be as strong as 43° over-proof; but the saleable strengths are from about 54° to 60°.

If British brandy, British rum, or cordials are to be made, the spirit is redistilled with various vegetable substances calculated to impart the requisite flavour.

All the various liqueurs, as condensed in the worm, are conducted by pipes into store-vats contained in a different part of the building; but in their way thither they pass through hollow vessels called 'safes,' similar in object and in principle to those before described.

# CHAPTER IV.

## MANUFACTURE OF VINEGAR.

There exists between the apparently dissimilar liquids wine, spirit, beer, and vinegar, a connexion little supposed by the majority of those who use them. Who would expect, unless he had attended somewhat closely to the matter, that the same corn which yields our quartern loaves may be made to yield spirit, and beer, and vinegar, by particular processes? Or that wine, cyder, beer, malt, sugar, and molasses, are all capable of yielding—and many of them are actually made to yield, in manufacture—that very distinct and peculiar liquid, vinegar? These are remarkable instances of vegetable chemistry, or of the changes which heat and other agents produce in vegetable substances. So far as regards beer and spirits, an outline has been given in the two previous Chapters; and a similar glance may be here taken at the farther stage—Vinegar.

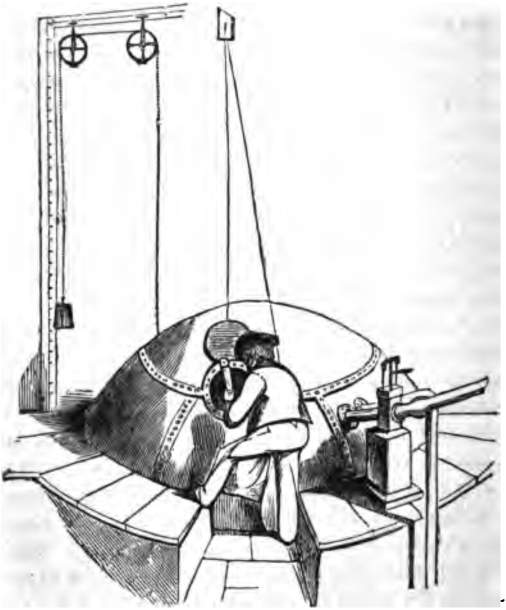
The vinegar-manufactories are but few in number. There are reasons, applying to these establishments as well as to porter-breweries and distilleries, why competition cannot be carried to so great an extent as in smaller undertakings. The 'plant,' or assemblage of apparatus, is very costly, and the skill required in the manufacture considerable. In a Report presented by the Commissioners of Excise Inquiry a few years ago, it was stated that the number of vinegar-makers in the United Kingdom is forty-eight, of which about half a dozen are in the metropolis.

All of these works exhibit large arrangements for corn-grinding, brewing, and other operations; and most of them also present a vinegar-field, a remarkable feature in such establishments. Here the eye glances over many hundreds of casks, all ranged in parallel rows, and elevated to equal heights from the ground on wooden bars resting on brick piers. A pathway lies open between each pair of rows of casks; and at intervals in these paths are openings or valves, forming channels of communication, to which we shall allude more particularly hereafter.

It was stated that vinegar may be produced from many substances apparently wholly dissimilar; but not only *may* they be, they *are* so in practice; for one manufacturer uses one ingredient, one another. Some establishments, for instance, are 'malt-vinegar factories,' where the vinegar is produced from precisely the same substance as the Highlander makes his whisky. It may be remarked, as a general clue to the apparent discrepancies in the materials of the vinegar manufacture, that alcohol, or spirit, is capable of being distilled from sugar, from fruit, from grain, and other vegetable substances; and that whatever yields spirit, may also be made to yield vinegar, by a different mode of procedure. Indeed the acetous fermentation, whereby vinegar is produced, follows very closely on the vinous, whereby spirit results; and it is often difficult to stop at the one and prevent the occurrence of the other. When we hear of 'sour' beer or 'sour' wine, we may regard these as instances that the acetous fermentation has commenced, or that our beer or wine actually contains some vinegar; indeed the French name, *vin aigre*, points significantly to one source whence the acid is produced.

Dismissing any discussion of the question why one manufacturer selects one ingredient and one another, we proceed to the details of the malt-vinegar manufacture, as exemplifying most of the principles involved. In this case, as in those of beer and spirit, the grain is 'malted,' in order that the starch contained in it may be converted into a kind of sugar; for it is from this sugar that the vinous fermentation produces alcohol, the parent of vinegar. Hence the early processes in an ale-brewery, a malt-distillery, and a malt-vinegar factory, are very similar.

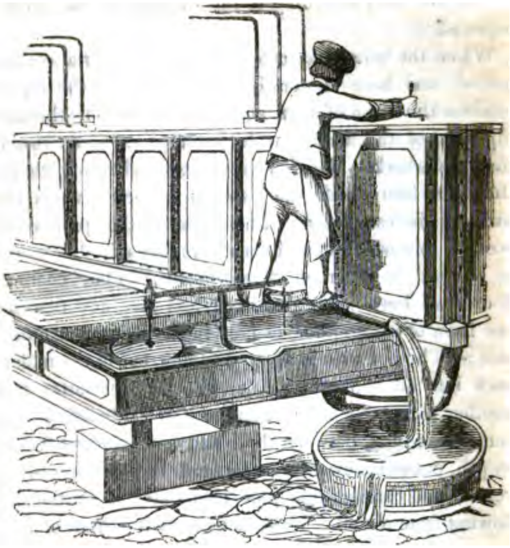
The malt is brought to the vinegar-works and deposited in store-rooms, from whence it is removed when a brewing is about to take place. (Vinegar-makers and distillers, as well as ale and beer brewers, give the name of 'brewing' to the extraction of a saccharine liquor from malt.) The quantity required for one brewing being measured out, it is ground into meal, either by mill-stones or by crushing-rollers. When crushed or ground, it falls through a hose or trunk into the mash-tuns in the floor beneath. These mash-tuns are similar in principle to those used at the great breweries and distilleries, but smaller in size. They are circular vessels with a central 'stirrer,' or instrument for keeping in constant agitation the ingredients which may be in the tuns; the stirrer being worked by a steam-engine. It is in these vessels that the 'saccharine fermentation' goes on, or the extraction, by the action of hot water, of a sweet or mawkish substance from the malt. It is this sweet principle which subsequently yields to the brewer his beer or ale, to the distiller his spirit, and to the vinegar-maker his vinegar; and it may well be supposed that every precaution is taken, and every investigation made as to the extraction of the greatest quantity and the most fitting quality of this important agent. The quantity of water required with a given quantity of malt, and the temperature at which the water is used, vary in each particular branch



Upper Part of the Copper or Boiler.

of manufacture, according to the strength of the 'wort' required.

When the water has acted on the malt for a certain period, and been constantly stirred with it, the liquor receives the name of *wort*, and is allowed to flow through pipes out of the mash-tuns into a large cast-iron vessel, the 'underback.' This is merely a general receptacle for the wort, into which the latter is collected when the mashing is completed. Then ensues the process of *cooling*, one which exhibits many remarkable differences as effected in different establishments. The 'cooling-floors' we have before described, and may now describe one form of refrigerator, as used in the vinegar-manufacture:—The hot wort is allowed to flow out of the underback into an oblong vessel, and out of this latter into another receptacle in the same part of the building. A continuous pipe, between three and four hundred feet in length, passes backwards and forwards through the oblong vessel, and through this pipe cold water is continually flowing from a well. There is a constant current of wort in one direction through the vessel, and a constant current of water through the pipe in an opposite direction; and it is not difficult to see that this must have a tendency to cool the wort. There are four adjustments by which the wort may be made to leave the refrigerator at any desired temperature, viz., increasing or decreasing the rapidity of the entrance of the wort, the exit of the wort, the entrance of the water, and the exit of the water. As the cold water travels onward through the convoluted pipe, it abstracts heat from the surrounding wort; when the water flows quickly, the wort is cooled to a lower temperature than when it flows more slowly; and by a



Underback and Refrigerator.

simultaneous adjustment of the valves connected with the wort-vessel, the flow of the wort can be also duly regulated. The above cut represents the refrigerator, at the end where the wort enters, and where the water leaves the pipe after having performed its office; by the side of the refrigerator is seen the 'underback.' Not only does this method require much less room than that of the 'cooling-floors,' but the time employed in cooling a given quantity of wort is reduced to one-third, and the manufacturer is rendered independent of fluctuations of the weather; for, unlike atmospheric agency, his cooling agent is brought from a source one or two hundred feet below the level of the ground, and is nearly equable in temperature at all times. It may be as well to remark that this method of cooling is the reverse of that adopted in the worm-tub of a distillery: in this latter case the hot liquid, or rather vapour, passes through the pipe contained in the vessel, and the cold water flows through the vessel itself; but in the vinegar-refrigerator the cold water passes through the pipe, and the hot liquid through the open vessel. The distiller's worm is not, in fact, a *refrigerator*, it is a *condenser*; and the condensed vapour must not be open to the atmosphere.

The reader will bear in mind that the wort thus produced is in principle precisely the same as that made by the ale and beer brewer and the distiller, differing only in saccharine strength. It undergoes, too, the same process of fermentation, subject to those limitations which may be required by the nature of the manufacture. From the refrigerator which we have just described the cooled wort flows into a large receptacle called the 'jack-back,' from which it is pumped up into vessels, called 'fermenting-tuns.'

To describe what goes on in the fermenting-tuns is no easy matter, as it involves the little-understood process of the vinous fermentation. The brewer, the distiller, and the vinegar-maker alike expose the wort to the action of yeast and an elevated temperature; but they require very different degrees of the alcoholic development. The brewer, when his wort has fermented, gives the name of *beer* or *ale* to the product, according to the manipulation of manufacture; the distiller calls his fermented wort by the name of *wash;* while the vinegar-maker applies the name of *gyle* to the fermented wort which he uses. It is very proper that distinct names should be thus used (although those actually employed may seem somewhat unmeaning), for the liquids are by no means the same, although all produced by vinous fermentation from sweet wort.

The fermented wort, or, as we shall now term it, the *gyle*, is transferred from the fermenting-tuns to other vessels, where it leaves a deposit or sediment, which is a kind of acetous yeast, and is then allowed to flow into a store-vessel, whence it flows into casks, where it assumes the form of vinegar, a process which is in every respect remarkable. The change here indicated is brought about in two methods exceedingly opposite in their general character. In the one case the casks containing the gyle are placed in close rooms heated to a high temperature; in the other they are ranged in rows in an open field, where they remain many months. Different as these methods seem to be, yet the effect produced is precisely the same, viz., the conversion of the gyle into vinegar by the internal process of acetification. In what manner the oxygen of the air and the heat of the stove-rooms work this change, is as much a chemical difficulty as the process of fermentation generally. As regards the convenience and interests of the manufacturer, both methods seem to have their advantages; for at some vinegar-works both are followed, although the one occupies a very much longer period of time than the other. When the vinegar is to be acetified in the field, it must be made during the three spring months, and then left several months in the field.

This process of acetification is technically called 'stoving,' or 'fielding,' according to the method followed. In the first-mentioned case, the casks containing the gyle are arranged conveniently in stove-rooms, which are closed and locked, and then exposed to a certain temperature till the acetification has been wrought. Two minutes' stay in one of these rooms is quite sufficient to convince a visitor that vinegar is in the act of formation, the suffocating acetous vapour being insupportable. The method of stoving is, we believe, generally adopted by the vinegar-makers of France, and appears to render the manufacturer more independent of the seasons than the field process.

The process of 'fielding' is much more visible, if we may use such a term, than that of 'stoving,' from the circumstances under which it is conducted. The casks, each of which contains rather more than a hundred gallons, are arranged in long parallel tiers, with their bung-holes open and uppermost. Beneath the path which separates every two rows of casks is a pipe, communicating with the 'back' at the top of the brewhouse; and in the centre of each path is a valve or cock opening into this concealed pipe. When the casks are about to be filled, a flexible hose is screwed on to this valvular opening, and the other end of the hose is inserted in the bung-hole of the cask. Then, as the reservoir of gyle is many feet above the level of the casks, the liquid flows by its own pressure through the underlying pipe and the hose into the cask. A man guides the hose in the manner represented in the annexed cut, and has sufficient length of hose to fill all the casks in one row, one after another.

Here the vinegar remains for several weeks, or even months, the bung-holes of the casks being covered with small pieces of tile or slate, which are removed when the weather is fine. The casks are examined twice every day; and if it happens that a shower of rain comes on suddenly while the bung-holes are exposed, nearly all the hands in the vinegar department are 'turned out,' to cover the casks as speedily as possible. The air effects the same object as the heat of the stove-rooms, but much more slowly. In both cases the gyle, or fermented wort, undergoes the process of acetification, whereby it becomes converted into vinegar. In those factories where the vinegar is produced from other substances than malt, the gyle is converted into vinegar nearly in the same way as

Vinegar-field—filling-in.

Vinegar-field—drawing-off.

in the present case, although the gyle itself is differently produced.

The vinegar, so far as acetification is concerned, is now finished; but there is a certain purifying or cleansing required before it assumes a marketable state. This purifying is, however, not always done immediately; but the vinegar is pumped from the casks into a store-vat, a centre from whence pipes conduct the liquid to a number of store vats placed in the 'vat-warehouse.'

When the vinegar is to be clarified or 'brightened' for sale, it is pumped from the store-vats into vessels which are in some respects the most remarkable employed in the vinegar manufacture, or rather the clarifying ingredient is a remarkable one. In a building called the 'rape-shed' are some enormous wooden vessels called 'rapes,' each of which is filled with a filtering ingredient also called 'rape.' This double employment of the same word seems rather absurd; but it is probable that the 'rape-vessels,' or the vessels containing 'rape,' became called 'rapes' for the sake of brevity; and for the origin of the name itself we may perhaps refer to the French word 'raffe,' connected with the process of 'raffinerie,' or refining. Leaving etymology out of the question, however, we may state that this rape consists of *raisin stalks and skins*, which seem to filter the vinegar better than any other substance hitherto employed. It would seem pretty evident that it is not a mere filtration which the vinegar undergoes, but that in percolating over and over again through the rape, it imbibes some quality which it did not possess before. Sometimes wood-shavings, sometimes straw, and sometimes tanners' spent bark, is employed as the filtering ingredient; but the refuse of raisins which have been employed in making wine is preferred to every other material. It is a matter of much difficulty to collect the necessary quantity of this material to fill the bulky vessels; and when once collected, there is no part of the vinegar-maker's apparatus on which he places so much value. We shall have a further remark to make on this subject in a future page.

Each 'rape,' or filtering-vessel, is fitted with a false bottom, on which the filtering medium is placed. Beneath this false bottom, and above the true bottom, is inserted a cock, which allows the vinegar to flow into a back or cistern. From this a pump elevates the liquid to the top of the vessel; and hence ensues a very curious circuit. The vessel is filled up with vinegar, which filtrates through the raisin-refuse into the space beneath, thence into the tank, thence through the pump to the top of the vessel, to recommence its circuit. Over and over again does this circuit proceed, the pump being kept constantly at work, and the vinegar incessantly in motion. If such a comparison might be permitted, we would liken the pump to a heart, which propels the liquid to the enormous lung—the rape—where it is purified, and then again returned to the heart. The filtering substance gradually, but very slowly, wastes away, and is renewed from time to time.

The vinegar by this process becomes transparent, or 'bright,' as it is technically termed, and is then pumped from the rapes into store-vats, where it is kept till required to be put into casks for sale, and the rapes are immediately filled up with an equivalent portion of fresh vinegar, so as never to leave the raisin-refuse idle. The vinegar-casks hold one hundred and sixteen, fifty, and twenty-five gallons respectively.

With a few miscellaneous remarks on vinegar we may terminate this chapter. Vinegar is known by certain numbers, such as No. 18, 20, 22, and 24. These originally represented the number of pence per gallon at which the vinegar was sold; and although the price no longer accords with these numbers, the numbers themselves have been retained as symbols whereby certain qualities of vinegar may be known and designated. Vinegar pays to government a duty of 2*d.* for every gallon of 'proof:' proof being deemed that degree of strength which contains five per cent. of pure acetic acid, as ascertained by an instrument called an 'acetometer,' which acts on the principle of determining the specific gravity of the vinegar when saturated with hydrate of lime, and deducing the acetic strength therefrom. Vinegar varies considerably in its strength under different circumstances, and the duty paid always bears a strict relation to the strength: thus, if the quantity of pure acid in a gallon of vinegar be double of 'proof,' then it pays double duty, or 4*d.* per gallon; and so on. The strength of vinegar is more difficult to ascertain than that of spirit, for there is a kind of mucilage or extractive matter in it which increases its specific gravity, and which is very different in quantity at different times. Hence a given specific gravity will not, as in spirit, indicate the strength; and the test employed is the specific gravity *after* it has been saturated with hydrate of lime. Up to the year 1834 there were seventy-seven thousand dealers in vinegar in Great Britain, every one of whom was visited once a month, to see that he conformed to certain regulations, such as to make an entry of his premises, and not to send out any quantity of vinegar exceeding ten gallons without a certificate from a book provided by the Excise. The expense of thus making nearly a million visits in a year, and the utter uselessness of the system, led to its abandonment in 1834, on the recommendation of the Commissioners of Excise Inquiry. The quantity of vinegar made in the British Islands is about three millions of gallons a year, of which more than half is made by four London firms.

# CHAPTER V.

## VINTAGES AND WINE-MANUFACTURE; BRITISH WINES.

It might perhaps seem scarcely consistent to describe the *foreign* wine manufacture in connexion with British industry; but as a mode of rendering clear the difference between foreign wines and those imitative liquids which are the only ones that can be produced in our own country, a few details may be allowable. We may take champagne, claret, and sherry, as examples of the class generally.

### *Champagne.*

There are no spots in England analogous to the wine-districts of France. The cultivation of the grape is in too backward a state in this country to allow of the wine-manufacture being brought to an important extent. Perhaps the nearest approach to such a system is exhibited in the cider-districts of Devonshire and Herefordshire, where the inhabitants, for one generation after another, cultivate large orchards of apple-trees for the express purpose of preparing this beverage. In the midland parts of France, however, the wine-system (if we may so term it) exhibits many interesting features worthy of note.

The name of *Champagne*, which is so familiar as that applied to a choice variety of French wines, is the name of one of the provinces into which France was divided before the Revolution. The province has been since subdivided into several "departments," and the old name is not now officially applied to the district; but if nothing else should keep the name of Champagne in remembrance, the wine which is named after it will effectually do so. The district of Champagne lies eastward of Paris, intervening between the metropolis and the country round Strasbourg. Rheims, Epernay, and Château-Thierry, are three of the principal spots in the heart of the wine-district: especially Epernay, on the road from Paris to Châlons-sur-Marne.

For the manufacture of the *white* champagne wines, black grapes are generally used. They are gathered in the morning while the dew is yet on them; and it is remarked that, when the weather is foggy at the time of the vintage, the produce of the fermentation is considerably increased. The wine obtained from the first pressure is called *vin d'élite*, and is always kept apart from the rest. The liquor is collected in small vats, whence it is removed early on the following day into puncheons which have been previously sulphured; in these the *must* undergoes a brisk fermentation, and is allowed to remain till towards the end of December, when it becomes bright. It is then racked, and fined with isinglass, and in a month or six weeks more it is racked and fined a second time. In the month of March it is bottled; after it has been six weeks in bottle it becomes brisk, and towards autumn the fermentation is often so powerful as to occasion a considerable loss by the bursting of the bottles: the loss thus sustained, which is seldom less than twenty per cent., is one of the causes which tend to enhance the price of the wines. To procure *pink* champagne, the grapes are first slightly trodden and freed from the stalks; and the fermentation is allowed to commence before they are subjected to the press, in order to facilitate the solution of the colouring-matter. In making the *red* wines, the grapes are trodden before they are introduced into the vat; sometimes the treading is repeated during the fermentation. The marc, or stalky refuse, is covered by a board, and a layer of straw is commonly employed to protect the frothy head from the contact of the atmospheric air.

Miss Costello, in her 'Pilgrimage to Auvergne,' has given many interesting details concerning the Champagne district, which further illustrate the place and its people. Wine-making is deemed such an important part of the industrial arrangements of the district, that pamphlets are continually appearing, as well as works of larger bulk, relating to professed improvements in the method of cultivating the vine, or in the manufacture of the wine. There does not appear, however, to have been much change in the mode of proceeding during half a century. At that time Arthur Young the agriculturist visited the wine-caves of Epernay, then the property of M. Lasnier and M. Dorsé; and the same caves are now occupied for a similar purpose by M. Moët, a wine-merchant whose name is well known to the connoisseurs in champagne. These wine-caves are quite remarkable, and unparalleled by anything of the kind in England. They form an intricate labyrinth of subterranean passages in some chalk-hills near Epernay. It would take a whole day to ramble all through them, and from one end to the other there is nothing but wine,

wine. When Arthur Young visited them, they contained fifty or sixty thousand bottles of champagne; but at the present time M. Moët is said to have the enormous quantity of three millions of bottles of this costly wine there deposited. The wine is kept in the caves three years before being sent out, and the quantity is kept up by renewals as fast as the old wine is removed.

The most advantageous position for planting the vines is on the south-eastern slope of a hill. The summits of hills are too much exposed to winds; while the bottoms of valleys and plains, although fitted for the growth of the wood of the vine, do not answer so well for the ripening of the grapes. In past times very great attention was paid to the choiceness of the growth, in order that this, rather than quantity, should give the reputation to the place. Philippe le Hardi issued an ordinance in 1395, expressed in these words:—"Understanding that on the hill where the best wine in the kingdom is grown, and of which our Holy Father the Pope, our Lord the King, and many other great lords are in the habit, by preference, of making provision, there has been of late planted *gamais*, a bad plant which has many times deceived and defrauded foreign merchants, by which much injury and loss has been sustained, it is hereby ordered that the *déloyal gamais* shall be cut and extirpated in a month from this time, under penalty of a fine of sixty sous each plant."

Those vines are said to be the best which are planted in *cordons* and run on trellises; but many are still grown on single props. It is not uncommon to observe, between the ranks of vines, beans and potatoes; but this is a custom not approved by the best judges. Judicious pruning is regarded as a point of the first consequence—as much so, indeed, as the position of the vineyard or the quality of the plant. The *vigneron*, or vine-dresser, is a husbandman on whose skill much depends; and it often happens that a person so engaged is himself a proprietor of vines: a state of things which sometimes leads to the neglect of his employer's vineyard while attending to his own.

The connexion between the flavour of the grapes and the flavour of the wine is not so close as many might suppose. It does not by any means follow that a grape pleasant to the palate produces a pleasant wine; for, in the course of the fermentation, and of the different operations necessary to bring out the real qualities of the fruit, many minute chemical changes occur, which render the quality of the wine a very uncertain point. The kind of vine called *pinot* is reputed to produce the best wine; yet there are but few champagne vineyards planted with it: because, though the wine is superior, the produce is so small that the expense of cultivation is scarcely compensated by the price. For this reason, this kind of grape is mixed with others of lesser value, to produce what is called *vin pinoté*. If the very finest kind be required, it is necessary to keep all inferior varieties at a distance; for if a pinot-vine be surrounded by inferior plants called tryons, the flavour of the fruit of each will partake of that of the other.

Miss Costello, after speaking of some disasters which the town of Epernay had suffered in the troubled events of former times, remarks:—"The vines, however, flourish through all troubles, and are not only splendid in quality, but beautiful to the eye. Indeed, the whole drive from Epernay to Château-Thierry, which was our next destination, is exquisite, constantly varied and picturesque, and glowing with abundance: corn, vines, and fruit heaping the earth with riches; gardens of roses and orchards of crimson cherries along the road, with every here and there pretty villas belonging to the wine-merchants peeping from their shrubberies, and prospects of extreme beauty opening from the summit of the hills, with the bright Marne winding at their feet."

The Rhône, as well as the Marne, presents its gently sloping hills clothed with vineyards. At a spot about two miles from Valence is the village of St. Peray, around which are hills on whose slopes an almost uninterrupted vineyard extends, producing very beautiful grapes, wherever a south-eastern aspect can be obtained. The grape when ripe assumes a beautiful golden hue; its taste is cloyingly sweet, and the saccharine matter which exudes often covers the branches with a brown stain. From these grapes is produced a sparkling wine of a wholesome quality and a delicate rosy tint. The vintage takes place about the middle or end of September, and the juice is at once transferred to the cask, before the fermentation has begun, and remains there for six or seven months, during which time it is fined. In March or April it is bottled, and remains two or three years to mature, and allow the dregs to deposit. The bottles are piled up in stacks, each row separated by laths, to allow the bottles which burst (and they form fourteen or fifteen per cent. of the whole) to be withdrawn. After this the wine is racked, that is, each bottle is taken out, and is thrust neck downwards into a hole cut in a board. By this means the dregs sink down gradually into the neck;

and as they descend, day by day, the bottle is tilted more and more until its position is nearly vertical. To expedite the falling of the sediment, the bottles are lifted and set down with a jerk once or twice a-day; and, after receiving two or three hundred of these jerks, the bottle is taken up, and the sediment is discharged by cutting the string and letting the cork fly, and with it the lees at the neck of the bottle, but as little of the wine as possible. The vacancy thus caused is filled with clear wine; and this process of corking and uncorking is repeated two or three times, until no more sediment is deposited.

### *Claret and Burgundy.*

The province of Burgundy adjoins that of Champagne on the south, and is in fact pretty nearly a continuation of the same wine-district. As Burgundy, however, is farther south than Champagne, it may have rather a warmer climate, and this may affect the fruit grown there. When Burgundy, under its dukes, was an independent state, the vineyards formed an important part of its riches, and have never ceased to be so under the kings of France.

There is a range of hills, called the *Côte d'Or*, which crosses Burgundy from north-east to south-west, and constitutes the heart of the wine-district. Wherever an advantageous slope towards the south or south-east presents itself, the country is entirely laid out in vines, which give it a rich though not perhaps a picturesque appearance. The Côte d'Or commences about a mile from Dijon, and continues to range at a distance of about a mile from the carriage-road; the hills attaining a height of seven or eight hundred feet. It is aptly described as a wall of hills, covered with vineyards, which form terraces on the sunny side, and then spread along the table-land on the summit. The name of 'Côte d'Or' may be interpreted as the 'Golden Slope,' and may either refer to the richness of the produce, or to a yellowish-red colour of the soil seen through the tufty vines. Here, as in Champagne, two adjoining vineyards, with no differences of situation that can be exactly appreciated, will produce qualities of wine widely different; showing that a great number of minute circumstances bear a part in producing the final result. The soil in which the Burgundy grape is produced consists in general of a light black or red loam, mixed with the debris of the calcareous rocks upon which they repose. The principal vineyards of the Côte d'Or are all situated between Dijon and Chaguy, and describe an arc of a circle exposed to the sun towards the south-east, and protected on the north-west by the hills behind them. The vines are planted in trenches, at the distance of about two feet apart, and are trained on poles to the height of thirty or forty inches. In the best vineyards they are extremely old; and when old vines are replaced by others, a larger crop is obtained, but it is of an inferior quality.

There is one Burgundy vintage at Côte d'Or very celebrated for the quality of its wine. It is called the *Clos de Vougeot.* This vineyard was once the property of the monks of the neighbouring Abbey of Cîteaux, who carried the culture of the grape to the highest perfection—never selling any of the wine, but giving away that which they did not consume themselves. Since then it has changed hands more than once; and Mr. Busby gives the following account of the mode of proceeding adopted at the present day:—

The vineyard contains about a hundred and twelve acres, and produces annually about two hundred hogsheads of wine. The soil near the top of the hill consists of small fragments of whitish limestone, mixed with shells, of which the hill is composed: in the lowest part of the vineyard it merges into a nearly pure clay; the vines nearest the top, in the dry soil, produce the best wine, while those in the lower situations produce the worst. The vintage is in general soon over, the proprietor employing four or five hundred vintagers at the same time. For the red wine, the grapes, as they are brought in, are thrown into large cases or troughs, and there trodden by a number of men with large wooden shoes, till the grapes are nearly all broken. They are then taken up in baskets, with interstices wide enough to allow the grapes to pass through; when a portion of the stalks, generally about two-thirds, are taken out. The whole is then put into a vat, into which the *must*, as it ran from the treading, had been previously put. A space of about twelve inches is left unfilled at the top of the vat, and a sliding lid is then put over, which floats upon the surface.

As soon as the fermentation becomes violent, the swelling of the mass lifts the lid to the height of six inches above the mouth of the vat, by the accumulation of the skins and stalks at the surface of the liquor. The fermentation continues from a day and a half to a fortnight, according to the state of the weather, the best wine being produced by the most rapid fermentation.

When the fermentation slackens, the liquor begins to subside, and the wine is then drawn off into large vats containing seven hundred gallons each. At intervals of three or four months it is pumped into another vat of the same dimensions. The Burgundy of Clos-Vougeot receives no other preparation but this, which is repeated several times, until the desired condition is attained. The age at which the wine is sold is from three to twelve years, the highest price being charged for that which has been kept longest. The quality of different vintages varies considerably: thus, the wine of 1824 was of such low value that it was given to the labourers as their ordinary drink; while that of 1825 was kept for many years as a choice vintage, and sold at a high price.

The *Claret* district of France is at a considerable distance from the provinces where Champagne and Burgundy are produced. The district of Médoc, rather northward of Bordeaux, and between the Gironde and the Bay of Biscay, is the heart of the Claret vineyards. Along the left bank of the river is a strip of land, a mile or two in width, thickly planted with vineyards, and constituting one of the most valuable wine-districts in France. The soil is a light gravel; and it may seem curious that the vine grows where hardly anything else will grow; the gravelly soil being fitted to retain the sun's heat about the roots of the plant after sunset, so that the elaboration of the juice seems to go on as well by night as by day. The vine is here trained exclusively on the espalier fashion, fastened to horizontal laths attached to upright posts, at a height not exceeding one or two feet from the ground, running in an uninterrupted line from one end of the vineyard to the other. Manure is scarcely used in the culture, only a little fresh mould being laid over the roots from time to time; but the plough is driven between the vines four times every season, alternately laying open and covering the roots, a process which is performed by oxen, which traverse the rows without treading on the plants. The vine begins to produce at five years of age, and continues productive sometimes when two hundred years old, provided its roots have found a congenial soil to penetrate with the fibres, which sometimes extend to a distance of forty or fifty feet.

The claret wines are classed into 'growths' according to their excellence, each particular vineyard producing a peculiar kind of wine. The Bordeaux wines, or clarets (the latter being the name by which they are more generally known in England), of the finest qualities are those produced at the vineyards of Château-Margaux, Château-Lafitte, Château-Latour, and Haut Brion. These are the names by which these kinds of claret are known among the merchants; and the average quantity produced in each season varies from about sixty to a hundred and sixty tuns in each vineyard; the tun containing four hogsheads. Then there are about ten others of 'second growth,' or inferior quality; and lower than these are the third, fourth, and fifth growths, decreasing in the scale of excellence. Sometimes a 'fifth growth' vineyard will be next adjoining to one of 'first growth,' and yet no one can explain clearly why they differ so greatly in quality. Sometimes a good season will bring up the 'second growths' nearly to a level with the first, while a bad season will so lower the quality of the 'first growths' as to render the wine unfit for the English merchants (who are the most fastidious among the purchasers of claret). When the wine is not good enough for England, it is consigned to Holland; and if too poor for that country, it is retained in France. England takes more than half of the 'first growths,' but very little of the others; Russia takes a good deal of the best; Holland is the great mart for the second quality; while the lower growths are consumed chiefly in France.

The characteristic of claret is not strength in alcoholic quality, but the possession of a peculiar aroma or 'bouquet;' and the clarets are somewhat modified for the English market by having a small addition of a wine of different quality, prepared at the Rhône vineyards. The total produce of the Médoc district, in average years, is about a hundred and fifty thousand hogsheads. The price of a hogshead of the first growth, in the cellars of the merchants at Bordeaux, is seldom under fifty pounds, which is raised to eighty by the time carriage and duty are paid. Sometimes the whole produce of the vineyard known as the Château-Margaux has been sold on the spot at a thousand francs the hogshead.

Miss Costello, in her 'Summer among the Bocages and the Vineyards,' gives a few lively sketches of a wine-district northward of that which we have just noticed—being on the banks of the Loire. In passing along the bank of the river from Saumur towards Tours, the *côteaux*, or hill-sides, are seen to be clothed with luxurious vines. "Here," says this lady traveller, "are the côteaux of Champigny, Savigny, and a host of others, whose wines are highly esteemed and seldom allowed to leave the country. All along this luxuriant range of hills every inch of ground is golden, and our driver expatiated with great goût on the perfection of their delicious produce. 'Here,' he said, 'in the great year, never to be forgotten in a wine country, 1834, these vineyards were one mass of the richest grapes; so excellent was their quality and so over-abundant their vintage, that the lowest priced wine for the poorest people was equal to that charged a franc a bottle in other years; unfortunately, many abused this advantage, and much sickness was the consequence: to be sure it was difficult to avoid being affected by the wine even though every one drank as usual, for a very different result ensued, one glass being as strong as a dozen of ordinary.' This man, who was extremely intelligent, told us some curious particulars of the customs and manners of the vignerons, who are a class quite apart from others; they are rich, industrious, sober, and respectable; keeping strictly to their own habits, marrying amongst themselves, and being altogether distinguished from their neighbours."

A master "vigneron," or vine-dresser, in this district, after his vintage is completed, and the husks of the grapes alone left, has boiling water poured upon them; the mixture thus produced is put into a cask, and allowed to ferment, until a drink is procured which is the strongest that either he or his men ever indulge in; for they rarely, if ever, exceed the bounds of temperance. The vignerons are not long-lived; their work is hard, and the doubled-up attitude in which they have to attend to the vines distorts the figure strangely. A French writer says of them:—"There is no culture so hard as that of the vine; no fruit more uncertain, nor which the earth yields with more regret, as if she wished to conceal the effect of her own fruitfulness. It is singular how men condemn themselves to an existence which, if forced on them, would be considered an intolerable hardship. All these ridges planted with vine-plants are cultivated by men necessarily bent to the earth: at the age of sixty they can only walk quite bent double."

### *Sherry.*

Sherry is so much the most important of the wines made in Spain, that the wine-trade of that country has relation almost wholly to this variety. The name is derived from *Xeres*, a town in the centre of the wine-district. This is a small town near Gibraltar, but deemed one of the richest in Spain in relation to its population, owing to the vast trade there carried on in wine. A few years ago, there was said to be a Scotch firm at Xeres who dealt largely in wine, and whose cellars at that place were enormous, the extreme length of the largest being more than three hundred feet, and the breadth two hundred. Their ordinary stock kept on hand was stated at four thousand butts, kept in casks of various sizes, holding from one to four butts each. Many other firms possess ranges of wine-cellars nearly or quite as large; and indeed the cellars constitute the principal buildings of Xeres.

The mode of culture adopted for the sherry grape, as described by Mr. Busby, who visited Spain for the purpose of inspecting it, is as follows. Immediately that the grapes are plucked from one vintage, a small pit is dug around each separate plant, to enable the rain to penetrate to the roots. In January the whole plant is pruned; and the pits are then closed, in order that the moisture which has been received may be retained. The soil is soon afterwards loosened and freed from grass and weeds, which is generally effected by the middle of March. The soil is carefully smoothed twice, with an interval of three weeks; the vicious sprouts are cut off at the roots of the plants; the soil is pulverized very finely; and stakes are driven in to support the coming crop. In the meantime there are numberless minor points requiring the attention of the husbandman, especially the search for insects; so that the demands on his care and labour are unceasing. But, on the other hand, the vintage is less uncertain than in some other countries; so that although the cultivator works hard, he feels pretty sure of an adequate return for his exertions.

The grapes are allowed to hang till perfectly ripe, which generally occurs rather before the middle of September. After the plucking, those growers who are most attentive to their wines place their grapes in baskets, and expose them to the sun for forty-eight hours, turning and sorting them all the while. When the wine is to be made, the grapes are carried to the pressing-room. The presses generally used in Spain are simply large wooden troughs, about eight feet square by twelve or fourteen inches deep; and each will contain at one time as many grapes as will yield a butt of wine: a coarse wooden screw stands in the centre of the trough, and is worked by a lever. A large quantity of grapes being heaped up in one part of the trough, the labourers commence by strewing upon them as much powdered gypsum as a man can take up with both hands. Some of the grapes are then spread over the bottom of the remainder of the trough, upon which the men jump with great violence, having heavy wooden shoes on their feet. After the greater part of the grapes are pretty well broken, they are piled up round the screw; and a flat band, made of a kind of grass, is wound round the pile, commencing at the bottom: the broken grapes being heaped and pressed in as the band is wrapped higher and higher, till they are all compressed into it. The men then commence working the screw, and the must or juice flows in great abundance. The bottom of each trough is elevated two or three feet above the floor of the cellar, with two or three spouts so arranged as to allow the must to fall into vessels beneath. The must is poured into butts; and the skins and husks, after having had water added to them, are again pressed, to yield an inferior quality of must.

The subsequent processes of fermentation, &c., are pretty nearly analogous to those observable in other wine-countries; but there is a difference between the kinds of sherry, which depends in a peculiar degree on the subsequent management of the fermented must. The difference between *light* sherry and *brown* sherry is stated by Mr. Inglis to be brought about in the following way:—If a butt of brown sherry be wanted, a butt of light sherry is boiled down to one-fifth part of its bulk, till it acquires a deep brown colour; and one-half of this quantity is added to a butt of the best pale sherry, of course removing from this latter as much as will make room for the boiled wine. The wine here called 'light' sherry is not an inferior quality; it is the produce of the

Xeres grape, planted upon a lighter soil near the mouth of the Guadalquivir, and produces a wine of rather lighter tint than that of other parts of the same district. This addition of the condensed light sherry to the brown sherry does not render the latter more expensive; because the former is produced from a more abundant and cheaper grape than the latter. By adding more or less of this boiled wine to other sherries, any desired tint may be given to them; and all the gradations of colour, which are by many supposed to have connexion with particular growths or vintages of sherry, depend mostly, if not entirely, on the quantity of boiled wine mixed with the unboiled.

The casks in which the wine is stored in the cellars at Xeres are arranged in regular rows, in some parts of the cellar to the height of four tiers. They are called *soleras*, and always remain in the cellars; they contain wine of all ages, from one year to half a century. The wine-merchants of Xeres never exhaust their stock of finest and oldest wine. According to the price at which wine expedited to the market is intended to be sold, it contains a larger or smaller proportion of old wine; but it is only in wines of a very high price that even a small portion of their finest wines is mixed. What is withdrawn from the oldest and finest casks is made up from the casks which approach them nearest in age and quality, and these are again replenished from the next in quality to them. Thus a cask of wine, said to be fifty years old, may contain a portion of the vintages of thirty or forty seasons. The principal wine-merchants of Xeres do not ship wine for England (the best, or nearly the best of their customers) till it has attained the age of two years; that is, till the bulk of the wine has attained that age; but the differences in quality and price are made up chiefly by the greater or less quantity of the choice wine mixed with it. The higher qualities of sherry are those of which the bulk is four or five years old, and which is also mixed with some of the choice reserve. Thus, every kind of sherry which reaches this country is a mixture of many different vintages: it may have been, perhaps, "seven years in bottle;" but before being bottled, and before leaving Spain, it was compounded from different sources.

The lowest-priced sherries are often brought from Malaga, which produces a wine, not, in fact, sherry at all; but they are sent to Xeres, and there "doctored" so as to pass for the wine of that district. All such wines have brandy added to them, to increase the strength. There is even a still further system of compounding different liquors together to make up the saleable sherry; for there is a very dry kind of sherry, called *montillado*, or *amontillado*, which has a very light colour, and which is used to reduce the colour of sherries when too high; in the same manner as boiled wine is used to heighten the colour when too pale. The montillado is made sometimes accidentally and at other times designedly: if it be intended to produce montillado, the fruit is plucked a fortnight sooner than for sherry; but so uncertain are the results of a vintage, that if a hundred butts of wine be procured from a Xeres vineyard, and treated in precisely the same way, several of them will, in all probability, turn out to be montillado, without the grower or the merchant being able to assign any reason for it.

Mr. Inglis says that—"Sherries, when adulterated, are not usually adulterated by the London wine-merchant, with the exception of those extremely inferior wines, which, from their excessive low price, no one can expect to be genuine wines, and which are probably mixed with Cape. But the class of wines which pass under the denomination of 'low-priced sherries' are not adulterated at London, but at Xeres, by the grower, not by the exporter. These wines are mixed with the wines of Moguer, and with a larger proportion of brandy; and the exporter, in purchasing them from the grower, is quite well aware of their quality; but, being ordered to send a large cargo of low-priced wines, he is forced to purchase and export these. It may be laid down as a fact, that genuine sherry, one year old, cannot be imported under thirty shillings per dozen; and if to this be added the profit of the merchant and the accumulation of interest upon capital in older wine, it is obvious that genuine sherry, four years old, cannot be purchased in England under forty-five shillings."

### *British Wines.*

Returning now to our own country, we find that 'British' or 'home-made' wines differ essentially from those above described. They are made either from dried grapes, which come to us under the name of *raisins*, or from common English fruits. At first the name of 'sweets' was confined principally to the varieties of raisin-wine; but as English-fruit wine was equally subjected to duty, all alike acquired the name of 'sweets.' The Excise definition of sweets is, "All liquors made by infusion, fermentation, or otherwise, from fruit or sugar, or fruit and sugar mixed with other materials;" and until 1834, any person who had any such liquor in his custody, in quantity exceeding one hundred gallons, was deemed a maker of sweets for sale, and subject to Excise survey.

The rise of the British-wine trade was closely connected with the vinegar manufacture, and dates back to about a century ago. At that time—as Hogarth's print of 'Gin Lane,' and many other sources of information, amply attest—the scenes of drunkenness witnessed in the metropolis had reached a fearful extent. The legislature endeavoured by various means to give a turn to the public taste that might lessen the evil; and among other things they held out strong inducements for the manufacture of sweets, or home-made wines, for sale. For many years, however, although sweets had been reckoned among exciseable articles ever since 1696, the manufacture continued utterly insignificant.

It happened about that time that Mark Beaufoy, a member of the Society of Friends at Bristol, who had abandoned his original trade of a distiller from conscientious scruples, arising out of the prevailing vice of the times, went to Holland to learn the process of malt-vinegar making, and on his return established a vinegar-factory on the site of the once celebrated *Cuper's Gardens*, near the present southern end of Waterloo Bridge. The works grew in extent and in fame, and were visited many years afterwards by Pennant, who in his 'London' gave a description of them. In the endeavour to establish this manufacture, Beaufoy had to encounter a great difficulty, viz. the want of '*rape*' wherewith to construct the filters to fine and flavour the vinegar. In Holland the vinegar-makers were supplied with the refuse from the raisin-wine manufacturers and raisin-wort distillers; but in England there was no source of the kind whence he could be supplied, and yet such a supply was indispensably necessary to the success of the process on the Dutch method. Under these circumstances he was constrained to purchase raisins, and after steeping them for the purpose of extracting the saccharine and mucilage of the fruit, the liquor was thrown away, and the rape alone (comprising all the solid parts of the raisin) reserved for use in the vinegar manufacture.

It happened, however, that Dr. Fothergill, the Quaker physician, became acquainted with this waste of raisin-juice, and, after demonstrating how wine might be made from it, advised Mark Beaufoy to commence it as a branch of manufacture. He did so, and entered his name at the Excise as a 'maker of sweets,' about a century ago; and his descendants have pursued the joint manufactures ever since. From that time, owing partly to the spur which one branch of manufacture thus gave to another, and partly to a wish in many quarters to substitute a milder drink for that which had produced such social evils, the raisin-wine trade rose into distinction and importance. The kinds of raisins he used were principally Smyrnas, Malagas, Lexias, Faros, and Cape de Verds; but in later years the manufacturers of sweets included the English fresh fruits among the materials whence they produced wine.

The manufacture of 'sweets' is one partaking of fewer processes than that of vinegar, and may be described without much difficulty. We may take the term 'sweets' in its fullest extent, so as to include all the varieties of British wine; but the only variety requiring description here is that of *raisin-wine*, to which the manufacture was in the first instance confined. All the kinds made from English fruits, such as 'currant-wine,' 'raspberry-wine,' 'elder-wine,' &c., are such household acquaintances, that we need not trace their birth and parentage; every 'Cook's Oracle,' and 'Complete Housewife,' and 'Kitchen Manual,' and 'Useful Receipt Book,' teaches us how to make these wines; and the difference between their methods, and the mode pursued by those who make the wines for sale, lies rather in the quantity operated on, and the size of the vessels, than in the routine of processes.

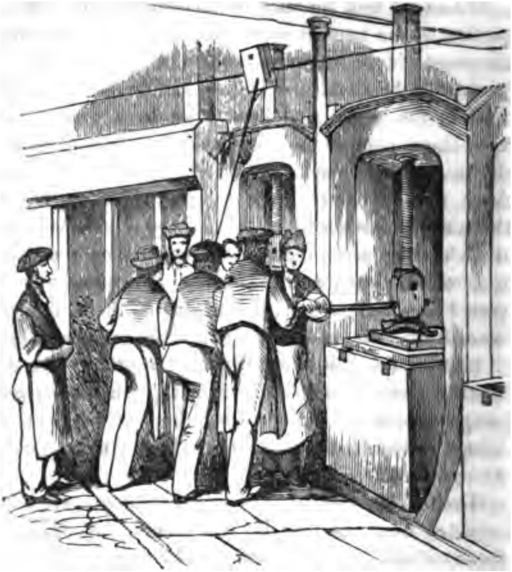
The dried fruits or raisins (frequently, but erroneously, called *plums*) which result from the different kinds of grape, do not lose all the vinous quality of the fresh fruit, although much seems to be lost in the process of drying. Nearly all the grapes thus prepared are brought from the countries bordering on the Mediterranean, and are generally named either from the places where they are produced, or those whence they are imported; but in some cases, such as 'muscatels,' 'blooms,' 'sultanas,' 'raisins of the sun,' and 'lexias,' the name is derived from the quality of grape or the mode of preparation. The most simple mode of preparation in the grape countries is to dry the fruit, after being cut when fully ripe, by exposure to the heat of the sun on a floor of hard earth or stone. Another method is to cut the stalks halfway through when the grapes are nearly ripe, and leave them suspended till the watery part is evaporated; the flow of sap is in a great measure prevented from entering the fruit, in consequence of the incision, and whilst evaporation continues to go on undiminished, the grape necessarily becomes dried. Some sorts are prepared by dipping the grapes in a ley, and afterwards drying them in the sun; the ley being formed of water, wood-ashes, and a small portion of oil of olives. Inferior raisins are dried by the artificial heat of an oven.

The raisins acquire very different qualities according to these modes of treatment; but the wine prepared from them by the British manufacturer of 'sweets' may be spoken of in general terms, without reference to specific differences, further than to say that the 'Lexias' produce a dry wine, the 'Denias' a sweet wine, the 'Black Smyrnas' a strong-bodied wine, and the 'Red Smyrnas' and 'Valencias' a rich and full wine. The time when the importer lays in his store of dried fruit is from Michaelmas to Christmas; and from thence to spring, or in short during the cool weather, is the principal time for making the wine.

The fruit comes into the hands of the wine-maker in three different kinds of packages—baskets, casks, and boxes—according to the quality of the fruit; but in general the raisins are packed closely together, and form a hard mass. These masses are in the first instance laid on a floor and beaten with wooden mallets, as a means of separating the raisins one from another. Sometimes the agglomeration is so close, that the mass has to be passed between rollers before the separation can be effected. The separate raisins—or rather the small masses, for the individual separation is not yet effected—are steeped in a vessel with a quantity of water, where they stand until all the fruit, by being swelled with the water, rises up and floats on the surface.

When the fruit has risen to the surface of the water, a portion of the latter is drawn from the vessel, by which the mass of fruit necessarily sinks to a lower level. A perforated board or floor is then laid on the top of the fruit in the vessel, and kept down by a weight; and upon this is pumped the liquor which had been previously drawn from the vessel. As the weight keeps the board down, and the board keeps the fruit down, it follows that the fruit has a body of liquid above as well as below it; while the perforations in the board allow the liquid to percolate through to the fruit. This process is repeated from time to time, by drawing off the liquid from beneath the fruit, and pouring it in above it, by which all parts of the fruit become equally affected. The extraction which is brought about during this process probably begins at the moment when the fruit has lightness enough to float on the surface of the liquid, and continues throughout the process.

When all the vinous and saccharine matters have been extracted from the fruit by this process, the liquid is drawn off into separate vessels. The fruit, however, is not wholly exhausted by this drawing-off, for a considerable portion of the liquid is absorbed by and mixed up among the spent fruit. To recover this is a point of importance; and the action of pressure is here brought into requisition. Screw-presses are often used for this purpose, such as that shown in the next cut. Each press consists of a kind of cubical box, two or three feet square, into which a strong square board or presser works, being attached to a screw above, and the screw being turned by capstans. In the first instance a man gets into one of the steeping-tuns, and lades out the spent fruit into baskets,



Wine-manufacture—Fruit-pressing.

which are carried to the press-boxes and there thrown in until the box is full. A powerful iron bar is inserted in a hole in the screw-shaft, and is then used, capstan-like, to turn the screw and press the fruit, half a dozen men being thus employed. Sometimes the aid of a powerful windlass is employed to turn the screw; and the pressure thus exerted is so great as to reduce the fruit to one-third of its former bulk.

The liquid which is thus obtained is added to that which was drawn off from the steeping-vessels; while the spent fruit, now pressed almost dry, is so far from being valueless, that it constitutes the article *rape*, so important to the proceedings of the vinegar manufacturer. The steeping is not the only process which is carried on in the large vessels; for after the fruit has been moistened and the saccharine qualities extracted, a kind of fermentation is induced by a leaven or yeast contained in the fruit itself; and it is principally to regulate this fermentation that the liquid is passed so frequently through the mass of fruit. In fact the liquid which is drawn off from the vessels is not merely raisin extract or juice; it is wine in a crude state.

The wine is pumped from the fermenting-tuns into other vessels in the store-warehouse. Here it is subjected to repeated 'rackings,' by which everything that is capable of being precipitated is separated from it and falls to the bottom of the vessels. Here too all the processes of sweetening, and 'fining' with isinglass, &c., according to the different kinds of wine, are carried on, until the wine assumes the form in which it is sold. It is stored in vats, from which it is drawn into casks for sale to the dealers.

# CHAPTER VI.

## SUGAR: ITS CULTURE, GRANULATION, AND REFINING.

MOST readers are probably aware that 'lump' or 'loaf' sugar—a holiday luxury to the middle classes, and, hitherto, an unattainable one to the humble—is prepared from common brown sugar by a refining process, and that this process is conducted in the buildings known as 'sugar-refineries.' In describing the mode of operation, we shall not find it necessary to trace the history of sugar in its previous states; but still a few remarks thereon will aid the object in view, by showing the successive conditions or forms in which the sugar is presented.

The external appearance of the plant which yields the sugar-juice has been thus described by Mr. Beckford:—"A field of such canes when standing in the month of November, when it is in arrow or full blossom, is one of the most beautiful productions that the pen or pencil can possibly describe. It commonly rises from three to eight feet or more in height, a difference of growth that very strongly marks the difference of soil or the varieties of culture. It is, when ripe, of a bright and golden yellow; and where obvious to the sun, is in most parts very beautifully streaked with red. The top is of a darkish green; but the more dry it becomes, from either an excess of ripeness or a continuance of drought, it assumes a russet-yellow colour, with long and narrow leaves depending;

from the centre of which shoots up an arrow, like a silver wand, from two to six feet in height, and from the summit of which grows out a plume of white feathers, which are delicately fringed with lilac dye, and indeed is, in its appearance, not much unlike the tuft that adorns this particular and elegant tree." The product of these canes is, first, a juice expressed from the cane; then a kind of syrup, from which impurities have been removed; and lastly, a brown granulated substance, from which a considerable portion of molasses, or uncrystallizable sugar, has been removed.

The ponderous sugar-hogsheads which we notice at the shops of the retail grocers contain moist sugar somewhat resembling in quality that which is imported by the refiner, but with a finer and softer grain. This sugar has various shades of brown colour, according to the quality; and the principal cause of this colour is, that a quantity of black molasses, or treacle, which formed part of the original cane-juice, is still mixed up with the crystallizable parts of the sugar,—not having been wholly removed by the processes to which the cane-juice is subjected before importation. The particles of sugar in their pure state are white; and to present them in this white crystalline form is the object of the sugar-refiner, who adopts means for expelling the molasses, and also certain impurities which are incorporated with the brown or Muscovado sugar as imported in the hogsheads.

Let us suppose, then, that a hogshead of moist sugar, imported from abroad, is brought to a refinery, and let us follow it through the routine of processes till it assumes the form of a conical lump of white sugar. This will enable us to describe the uses of the various buildings and rooms forming a large sugar-refinery. The hogsheads of sugar, having been brought in waggons from the docks to the refinery, are hauled up by a crane, and drawn in at an open door to a large room. The hogsheads are opened, and the sugar is transferred from them to a wooden floor, from whence it is shovelled into large circular vessels called 'blow-up cisterns;' so named in allusion to the mode in which steam is admitted to the contents of the vessels. The cisterns are six or seven feet in diameter, and about five in height; and the purpose for which they are employed is to dissolve the sugar preparatory to the removal of earthy and other impurities with which it is contaminated. The reader must bear in mind that notwithstanding the purifying processes whereby cane-juice is converted into brown sugar, there are still three kinds of substances which require to be removed from this sugar before the white crystalline state can be obtained, viz., earthy and other impurities, colouring matter, and molasses; and that very distinct processes are resorted to in order to effect the removal. To remove the impurities is the first object. The sugar is, as before stated, thrown into the 'blow-up cistern;' and water is admitted to it. Into the cistern containing the sugar and water is pumped a small quantity of lime-water. A steam-pipe, in communication with a boiler, is enclosed within the 'blow-up cistern;' and apertures being opened, steam is forced or 'blown' by its own pressure into the solution, by which the latter becomes heated in a very short space of time. This is one of the many instances in modern manufactures illustrative of the advantages derived from the use of steam as a heating agent. The water in the 'blow-up cistern,' being heated by the steam, dissolves the sugar; aided by constant stirring by means of long poles or oars.

This part of the process is one in which great improvements have been made of late years: indeed the same, to a certain extent, may be said of nearly all departments of the refining business. Under the old mode of proceeding, the sugar was dissolved in lime-water over an open fire, whereby it was subjected to a variable temperature injurious to the quality of the sugar; the clarification was effected by the admixture of a large quantity of bullock's blood, and a scum several inches in thickness was allowed to collect on the surface of the vessel containing the sugar, and was thence removed by a broad skimmer. This having been repeated two or three times, the solution of sugar was allowed to flow through a wooden channel into an oblong basket covered with a blanket, through which it filtered into a cistern below, carrying a considerable portion of impurity with it. But in the modern process, the desired effect is produced in a much more efficacious manner; for the temperature of the solution is not greater than that of boiling water; and the offensive clarifying ingredient is almost entirely dispensed with, the process of clarification, or the removal of impurities, being principally effected in the next process. The saccharine solution—called, in the language of the refinery, 'liquor'—is, in this case, not skimmed at all; but at a certain stage in the operation it is allowed to flow from the 'blow-up cistern' into a range of filtering-vessels in a room beneath; into which filters it enters as a thick, opaque, blackish liquid, and leaves them in a beautifully transparent state, though coloured of a reddish hue. One form of filter now used is exceedingly ingenious. Several cast-iron vessels, about six feet high, each contain sixty cloth tubes, about three inches in diameter, attached to short metallic tubes which are screwed to circular holes in the upper part of the vessel, and hanging vertically downwards. Each tube contains a large bag, made of a close kind of cotton-cloth, and coiled up so as to make the whole a compact mass of cloth; and the bags being each two feet wide and six feet long, it is easy to calculate that there are nearly fifteen hundred square feet of cloth comprised in each filtering-vessel. The 'liquor,' then, flows from the 'blow-up cisterns' into a shallow vessel to which these tubes are attached, and thence through the bags contained in the tubes. The bags being closed at the bottom, no outlet exists for the liquid except through the meshes or interstices of the cloth; and as the cloth forming each bag is doubled and redoubled in its tube, the liquid finds its way between the plies or folds of the cloth, and finally exudes in a transparent state. The whole of the impurities, with the exception of a little colouring matter, are retained by the bags and tubes, while the saccharine liquor passes through.

It must be evident that the impurities left in the bags would soon clog the meshes if not removed. At intervals, therefore, the tubes are unscrewed, and taken out to a washing-yard, where the bags are drawn out, the impurities removed, and bags and tubes thoroughly washed. These impurities still contain a small portion of saccharine matter, which is subsequently extracted from them by boiling and other processes; and the spent residue is finally sold as manure, for which it possesses valuable qualities.

The state to which the sugar in its progress has now been traced is that of a transparent liquid having a reddish tinge. To remove this tinge, without interfering with the transparency of the liquid, is the next object of attention, and charcoal is the agent which modern inquiry has shown to be best fitted for this purpose. It has been long known that common wood charcoal possesses the property of removing, more or less, the odour proceeding from animal and vegetable substances in a state of decomposition; but it was also discovered by the German chemist Lowitz, that the same substance will remove the colour from common vinegar and several other liquids: a fact which soon afterwards led to the employment of charcoal in the clarification of various pharmaceutical preparations, and as an auxiliary in the refining of sugar. About thirty years ago, M. Figuire, of Montpellier, ascertained the additional important fact, that charcoal obtained from animal substances is not only equally efficacious when used in considerably smaller proportion than vegetable charcoal, but that it is capable of decolouring many liquids on which the latter has no sensible effects whatever. The sugar-refiners immediately availed themselves of the knowledge of this fact; and since that time many different modes have been adopted of employing animal charcoal (or charcoal from burnt bones), in refining.

All the liquor, as it leaves the filters, flows through pipes into charcoal-cisterns, each of which is a square vessel. four or five feet in height, and provided with a double bottom, the upper one being perforated with small holes. On this perforated bottom a piece of cloth is laid, and on the cloth a layer of powdered animal charcoal, or 'bone-black,' nearly three feet in thickness. The saccharine liquor flows on the surface of this charcoal bed, through which it slowly finds its way, percolating to the bottom, then through the meshes of the cloth, and lastly through the perforations into the vacant space beneath. The effect of this filtration is very striking; for the liquor, which, though transparent, is of a reddish colour when it flows into these cisterns, leaves them in a state of colourless transparency almost equal to that of pure water. Such a complete decoloration is the best proof of the success of the modern improvements in this branch of manufacture. The cloth bags, and the arrangements by which the liquor is made to flow through them, remove all the opaque impurities; while the charcoal, and the apparatus of which it forms a part, remove the colouring matters from the filtered liquor.

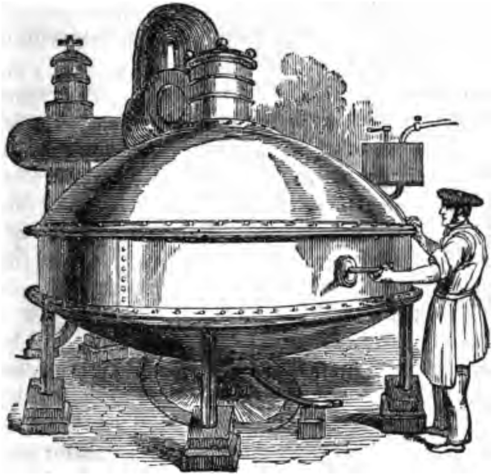
Every one knows that 'loaf' sugar, as well as 'moist,' possesses different degrees of whiteness and clearness of appearance. The mode in which these different qualities arise we shall presently state; but it may be here remarked, that it is only the finest qualities which present the pure and colourless appearance alluded to above, after passing through the charcoal. The inferior kinds retain a slight tinge of colour.

The 'liquor' consists of sugar capable of assuming a crystalline form—molasses, or uncrystallizable sugar—and water; and the object of the next process, that of 'boiling,' is to drive off a portion of the water in the form of steam, and to prepare the sugar for crystallizing. Under the old system the saccharine liquor was poured into a large copper vessel called a 'pan,' and there boiled over an open fire, at a temperature gradually rising to

230° or 250°, until the evaporation had caused it to assume a degree of viscidity known by experience to be proper for the purpose. From the pan it was emptied into vessels called 'coolers,' where it was beaten violently with an oar or staff, by the action of which the sugar was so far disentangled from the molasses as to be able to granulate, or become partially crystallized. It was found, however, that, independent of other evils, the sugar was liable in that process to be injured by the high temperature at which it boiled; for there is a tendency to decomposition even at the temperature of boiling water; and at a still greater heat the tendency is increased. These circumstances led to the happy suggestion, by Mr. Howard, of a method of boiling the sugar in vacuo. In the common operations with which we are familiar, boiling water is always nearly of one temperature, because it is exposed to a tolerably uniform atmospheric pressure; but if this pressure could be removed by the action of the air-pump, or some other means, boiling would take place at a temperature so low that the hand could bear it with impunity. So likewise in the case of sugar-liquor: if the pressure of the atmosphere could be removed, the process of boiling, which is nothing more than a very rapid evaporation, would take place at so low a temperature that the sugar would not be injured by it, viz., from 130° to 150°, that is, one hundred degrees lower than under the atmospheric pressure. Such were Mr. Howard's views; and few scientific suggestions have ever been attended with more complete success. Nearly all the principal sugar-refiners now boil sugar in vacuo, more or less perfect; each one adopting a form of apparatus or a routine of processes best suited to the circumstances under which he conducts his business.

The pans are circular, domed, copper vessels, from six to seven feet in diameter, and nearly the same in height. No fire is visible beneath them; the heating power being supplied by steam. Each pan is completely covered in, air-tight; but there are many channels of communication with other vessels: one admitting liquid sugar to the pan, another furnishing a channel through which it may flow out; a third admitting steam for boiling the sugar; and a fourth serving as an exit for the air originally contained in the pan, and also for the steam evaporated from the sugar. Various pieces of mechanism are attached to each pan, whereby the temperature of the liquid, the quantity contained in the pan, &c., may be tested; but these need not be further particularized. The external appearance of each pan, and the appendages belonging to it, are seen in the subjoined cut.

The process, then, is briefly this:—The liquid sugar, after percolating through the charcoal, and being collected in a cistern several feet below the pans, is placed in communication with them by an ascending pipe; and the air being withdrawn from within each pan by means of an air-pump, the liquid sugar ascends the pipe into the vacuum by atmospheric pressure from without, on the same principle as the water ascends in a common pump. Steam is then admitted to a vacant space below the sugar in the pan, and also through pipes traversing the interior; and by these means the sugar is brought to a boiling state while comparatively at a low temperature, on account of the tolerably perfect vacuum existing above the surface



of the liquor in the pan. As the evaporation proceeds, the vapour flows through a large iron pipe into a cistern, where cold water condenses it as fast as it is formed, and thus maintains a vacuum within the boiler. The sugar by this evaporation thickens and becomes partially granulated or crystallized; and to ascertain how far this process has extended, a most ingenious instrument, called a 'proof-rod,' is used, by which a small quantity of sugar may be taken out without disturbing the vacuum in the pan. This 'proof-rod' may be regarded as a key which unlocks a little valve in the body of the pan, draws out a sample of sugar, and locks the valve again. A hollow tube is fixed in the pan, with the outer end exposed to the atmosphere, but the inner end immersed in the liquid sugar. This inner end is constructed with a socket and plug, like the key of an ordinary liquor-cock, with two apertures through which, when open, liquor may flow. The 'proof-rod' is a straight brass rod with a handle, having a key at the farther end, which, on being introduced into the tube and turned round, unlocks the socket and plug in the tube, and allows the liquid sugar to flow through the apertures of the socket and plug into a recess at the bottom of the key. The proof-rod being again turned, locks up the apertures in the tube, and on being withdrawn brings with it a small sample of liquid sugar.

The attendant 'boiler' then tests the state of the sugar, by taking a little between the thumb and finger, and trying what degree of tenacity and granulation it has acquired. If the result is not satisfactory, the boiling is continued for some time longer; but if satisfactory,—and this is a matter that requires constant experience to determine,—a valve at the bottom of the pan is opened, and the sugar flows through a pipe into a room beneath, where vessels are placed for its reception. The sugar, as it flows through, appears to be much altered, for it is now a mass of crystals enveloped in a dark-coloured syrup.

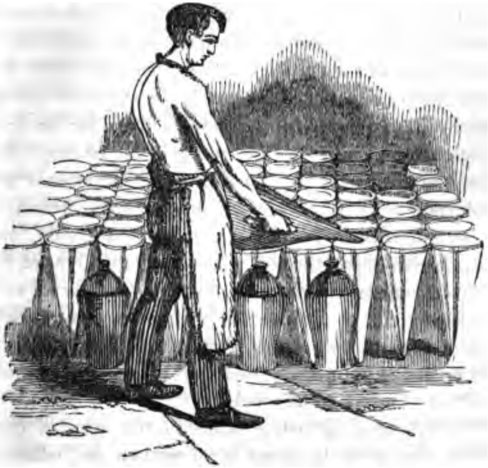
One of the most marked points of difference between the old and the recent methods of boiling is this:—that under the old system, the temperature at which the concentration was carried on was so high, that crystallization could not take place till a subsequent cooling had been effected; whereas under the system introduced by Mr. Howard the crystallization actually takes place to a considerable extent in the boiler itself. The sugar flows from the pans into vessels called 'heaters.'

It is a curious circumstance, that under the old system the corresponding vessels were termed 'coolers,' as being at a much lower temperature than that at which the sugar was boiled in the pans; but they are now called by an opposite name, because the sugar is here raised to a temperature of about 180°, having previously been boiled at 135° or 140°. While being raised to this higher temperature, the sugar is kept constantly stirred; and at a certain point in the process it has acquired a state which renders further heating unnecessary. The object of this process is not so much to crystallize the sugar (for that has already been effected in the pan), as to impart to it a consistence which facilitates the subsequent processes, and gives to the loaf of sugar a firmer texture.

Recalling to mind what has been already stated, it will be seen that the sugar has been successively deprived of its solid impurities, its colouring-matter, and of some of the water which had been mixed with it; but the molasses, or uncrystallizable parts of the sugar, still remain. To separate these, therefore, is the object of the next few processes, technically termed 'filling-out,' 'washing,' and 'netting.'

The 'fill-house' is generally a large room, on the basement story, paved with stone. A considerable portion of the floor is at most times covered with iron conical moulds, about two feet in height, and six inches in diameter at the largest part; each one placed with its apex downwards, and upheld by those with which it was surrounded. Hundreds, and probably thousands, of these moulds are thus ranged in close rank and file; some filled with sugar from the 'heaters,' others in the act of being filled, and the rest empty, waiting to be filled at a subsequent part of the day's operations. These are the moulds which give the well-known 'sugar-loaf' shape to the masses of white sugar seen at the shops of the grocers. Among the improvements which the business of sugar-refining has undergone, is the substitution of iron moulds for those made of clay; the latter used to be universally employed, but the former possess many advantages, and have almost superseded them.

The mode of filling the moulds differs in different establishments. In one it is as follows:—A number of men, each stripped from the waist upwards, are engaged in this duty; each man carrying before him a large copper basin shaped somewhat like a coal-scoop, and capable of holding above a hundredweight of melted sugar. The men fill their scoops with the hot viscid sugar, and walk, or rather run, with a quick elastic motion, to the moulds, which they fill one after another with the sugar. Each man, as soon as he has exhausted his cargo by filling three or four moulds, hastens back to the 'heaters,' fills his basin again, and returns to fill other moulds. It might be supposed that the men would be scalded by the liability of the sugar being spilled from the vessels; but practice enables them, by a peculiar spring of the body, to hasten along at a tolerably quick pace, without much personal inconvenience from the



heated sugar. As it is important to have all the sugar poured into the moulds while in a certain state of temperature and granulation, a sufficient number of men is employed to 'fill-out' all the contents of one sugar-boiling in about half an hour. When the moulds are filled, and the contents still in a fluid state, the surface is stirred and scraped round the edge of the sugar, to prevent any adhesion to the mould, and also to enable the small crystals which are forming to diffuse themselves equably through the sugar.

These moulds, then, contain sugar and syrup mixed up together, in a heated and viscid state; and in the 'fill-house' they remain till the following day, in order that two effects may be produced, viz., the solidification of the sugar in the act of cooling, and the partial separation of the syrup from it. When these objects are to a certain degree effected, the moulds are conveyed to upper rooms of the building, where the sugar is to undergo the processes of 'washing' and 'netting.' Every mould-full of sugar requires several days for its final completion; and thus each mould is in use so long, that a very large number is required for the purposes of the establishment, and many separate stories are necessary to contain them. In going from room to room, and from floor to floor, a visitor would see repetitions of the same arrangements, viz., moulds ranged nearly all over the floors of the apartments, as thickly as they could stand; there are in some refineries, and at some periods, twenty thousand of them filled with sugar, besides those which are waiting to be filled.

A small opening being made in the apex of each mould, the mould is placed in an earthen jar, where it is left for some time. During this period the syrup flows or drops out slowly, through the perforation, into the jar beneath. When this draining has proceeded to a certain extent, the mould is taken out of the jar, and the syrup, under the name of 'green syrup,' is emptied from each jar into one common funnel or pipe, by which it is conveyed down to the boiling-house. As this syrup still contains a portion of crystallizable sugar, it is boiled over again, with raw sugar, to produce lump sugar of a rather inferior quality; and when all the crystallizable sugar is obtained from it, the residue becomes the well-known substance *treacle*.

This draining, however, does not remove all the syrup from the sugar, a portion being still entangled among and coating the crystals; and to separate this portion, the sugar is 'washed' in rather a peculiar way. Formerly a process of 'claying' was adopted; a stratum of fine white clay diluted with water being laid on the surface of the sugar, the water percolated through the sugar by its own weight, mixing with the syrup which yet remained in the body of the sugar, and washing it away through the orifice in the apex of the mould. By the modern improvements, this porous surface, or sponge, as it may be considered, is formed of sugar instead of clay. The rough and uneven surface of the sugar on the base of the mould is scraped off into a vessel, and there mixed with water to the state of a 'magma' or mortar, which is again laid on the surface of the sugar. When this magma has acquired a certain degree of dryness, a clear solution of very fine sugar in water is poured on it, and allowed to remain. This solution, finding its way slowly through the mass of sugar beneath, carries with it the greater part of the syrup still remaining, together with a portion of good sugar which unavoidably accompanies it. This richer syrup, technically called 'second runnings,' is emptied from the earthen jars into a funnel which conveys it to the boiling-house, again to be boiled for the separation of the sugar from the molasses. The solution of sugar is renewed from time to time, until the syrup is so thoroughly washed away as to leave the loaf of sugar in a beautifully white state; or if the sugar be of a cheaper quality, until a corresponding degree of purity has been attained. The substitution of sugar for clay as the sponge-like layer placed in the moulds, is one of the many improvements introduced by Mr. Howard; and its importance is shown by the fact, that the process is now effected in one-fourth of the time which it used to occupy under the old system.

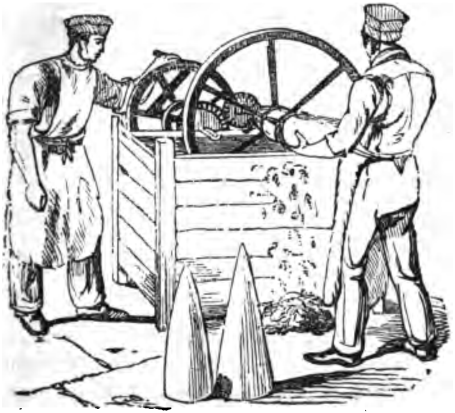
A medium kind of sugar, called 'clayed,' or Lisbon sugar, is much used in some foreign countries, and forms a link between moist and loaf sugar. The brown cane-juice, at a certain stage of the process, instead of being put into hogsheads, is placed in conical pots, called by the French 'formes,' with the points downwards, having a hole about half an inch in diameter at the bottom, temporarily closed with a peg. When the sugar in these pots is cool, the apex is opened, and the pots placed over jars. After this a 'claying' process is pursued, nearly similar to that alluded to above. The result of this process is, that after remaining fifteen or twenty days in the moulds, the sugar assumes a form more white and pure than that of raw sugar, but less so than refined. But it would appear probable that this old method will not be much longer pursued.

Returning to the refining processes, it will be evident that the quantity of syrup which drains from the apex of each mould is very considerable. In the first place, there is the 'green syrup,' which flows as soon as the hole in the apex is opened; and afterwards there are the finer syrups, resulting from the solution of fine sugar which is poured on the loaf or lump in the mould, and which carries off a portion of good sugar together with molasses. The subsequent boiling and preparation of those syrups, in order to obtain the crystallizable sugar from them, is almost as important an affair as the refining of the original brown sugar. A curious scale of qualities is maintained in these circumstances. The finest syrup is mixed with other sugar to obtain refined sugar of the same quality as that from which the syrup was obtained; the second quality of syrup assists in the preparation of sugar one degree lower in quality; while the coarsest, or 'green syrup,' produces a kind two degrees lower. Thus the finest syrup from the finest sugar is almost as pure as the sugar itself; while the coarsest syrup from the coarsest sugar is so thoroughly exhausted of crystallizable particles, as to be dismissed from the refining processes, and sold as treacle.

The face of the sugar in the moulds becomes rough and uneven, from the subsidence of the solid parts of the solution. When the 'washing' or 'netting' (*i.e.*, making the sugar net, neat, or pure), therefore, is completed, this face is made smooth. A man places the mould on its side across a stool, and scrapes the base or open sur-

face of the sugar with a small instrument; a process which is called 'brushing-off,' an odd term, considering that no brush is employed. The sugar is then allowed to remain a day or two in the mould, in order that the base may acquire hardness and firmness. A smart blow or two of the edge of the mould against a wooden post loosens the sugar within, and the loaf is turned out upon its base, after having lain in the mould for several days. We are then enabled to see the effect of the cleansing processes which the sugar has undergone; the surface is hard, crystalline, and more or less white according to the quality; the finest quality now made having a degree of whiteness almost rivalling that of snow. In no part of the manufacture have the modern improvements produced more decided effects than in the purity of colour now obtained. The inferior kinds of sugar retain a tint more or less dark, probably from the impossibility of expelling all the molasses from them.

The loaves or lumps (in the language of the refinery, 'loaves' are the finest quality, and 'lumps' somewhat inferior) of sugar are not, however, equally white all over when they leave the moulds: the parts near the apex being slightly damp and discoloured at the surface. To remove this damp portion, an ingenious machine is employed. Three cutting knives or blades are ranged in a conical form, and made to rotate by the motion of a wheel; and the apex of the loaf of sugar being introduced into the cavity formed between these blades, the surface is shaved or sheared off, leaving the body of the



loaf clean and smooth. Some of the larger and coarser lumps of sugar are not treated in this careful manner; but the damp apex is merely chopped off, leaving the lump as a truncated cone. The operation of shearing the surfaces of the loaves is termed 'turning off;' and the waste sugar obtained thereby, as well as that which results from the process of 'brushing off,' is melted and clarified, and converted into the fine clear solution which is poured on the sugar for the process of 'washing.'

After the loaves have been left several hours, ranged over the floors of large rooms, they are taken up one by one, wrapped in paper, and placed in an oven or stoving-room, where they remain until thoroughly dried; after which they are taken out and wrapped in blue paper, in which state they may be deemed finished.

A few words may, in conclusion, be given respecting the mode of reducing sugar to the state called sugar-candy. The process is not conducted at sugar-refineries, but is nearly as follows:—When the cane-juice has been clarified and boiled, it is placed in old moulds, having their lower ends stopped with linen, and crossed at intervals with strings or small twigs, to retain the sugar as it crystallizes. The moulds are then deposited in a cool place; and in proportion as the syrup cools, crystals are formed. In about nine or ten days the moulds are carried to the stove and placed in pots, and a small aperture made, through which the syrup can drop slowly. When the syrup has drained off, and the crystals of sugar-candy are become dry, the moulds are taken from the stove and broken in pieces to disengage the sugar, which adheres strongly to the sides of the moulds. By previously tinging the syrup with cochineal or some other colouring substance, the candy may be made to assume any desired hue. The arrangement of the utensils used in this process is generally somewhat as follows:—A stove is set apart, the entrance into which is on the ground-floor, as near as possible to the pans: the top is usually from ten to fourteen feet above the ground, and covered like the top or crown of an oven. Beams are fastened into the wall, at a distance of about twenty-six inches from each other, and sufficient to bear a very large weight; upon which strong planks are laid when wanted. The candy-pots are placed upon the planks, and remain there till the process is finished. The pots are usually made of thin copper, without feet, and are perforated round the lower part with numerous holes, the purpose of which is this:—a coarse white thread is drawn by a needle through a hole in one side of the pot, carried across to a similar hole in the other side, brought back again through a third hole; and so backwards and forwards till the lower part of the pot is traversed by several lines of thread; after which the holes are stopped. Each string forms a nucleus round which the candy crystallizes; an effect which used formerly to be produced by the use of small twigs.

# CHAPTER VII

## TOBACCO, ITS CULTURE AND MANUFACTURE; CIGARS; SNUFF.

"TOBACCO," says Mr. Porter, "is perhaps an object of more general use than any other production of the vegetable kingdom; and if we consider that in no sense can it be classed among articles necessary for human subsistence, the fact is calculated to excite our surprise as well as interest. The love of tobacco is evidently an acquired taste; yet is one so easily and universally acquired, that this weed forms a luxury which is enjoyed in common by the African negro, the unclothed and houseless wanderer of Australia, the hardy American Indian, the slothful Asiatic, and every class of people throughout the more polished countries of Europe." The steps by which this remarkable plant is brought into usable form will engage our attention in this Chapter.

The botanical name for the tobacco-plant is *Nicotiana*, given to it in honour of Jean Nicot, Lord of Villemain, who was ambassador from France to Portugal about the time when the plant was first brought to Europe. It is supposed that he introduced it first into France, as Sir Walter Raleigh did into England. There are seven species of the Nicotiana, of which the principal is the *Nicotiana Tabacum*. There are two varieties of this species, both annual herbaceous plants, rising with strong erect stems to the height of from six to nine feet, their foliage being fine and handsome. When full grown the stalk near to the root frequently attains a size greater than an inch in diameter; it is surrounded by a hairy clammy substance of a greenish-yellow colour. The leaves, which are of a light green, grow alternately at intervals of two or three inches on the stalk; they are oblong and spear-shaped; those lowest on the stalk are about twenty inches long, and they decrease in size as they ascend, the top leaves being only ten inches long and five broad. The young leaves, when about six inches long, are of a deep green colour, and rather smooth; but as they approach maturity, they assume a yellowish tint, and have a rougher surface

In cultivating the plant, the seed is sown in nursery-beds, called *patches*, bordered by some plant which will arrest the progress of the ravaging fly; and is effected generally about March or April. In a month's time the young sprouts being ready for transplanting, ground is prepared for their reception. Hillocks, about eighteen inches high, are raised in parallel lines, four feet apart in one direction, and three feet in another. The sprouts, being about five inches high, are carefully taken out of the ground without injury to their tender rootlets, and conveyed to the field in a basket. One person places a sprout upon every hillock; and others, who follow him, make a hole with their fingers in the centre of each hillock and deposit the tobacco-plant in an upright position, pressing the earth round the root with their hands. This is an operation of great delicacy, as the leaves are exceedingly tender at this time, and any injury sustained by them would endanger the safety of the plant.

Incessant attention is required to the young plants; and when they are in a fit state for being cut (at which time the leaves have changed their colour to a yellowish-green, the substance of the leaf is thickened, and the web more prominent), the cutters, each of whom is furnished with a sharp strong knife, proceed regularly along the rows of plants, cutting only such as appear to be ripe, leaving the rest for future operations. This selection is necessary, because if the tobacco be cut before it is fully ripe, it will not assume a good colour, and will be liable to rot when packed in the hogsheads. The stalks are cut almost close to the ground; and such of them as are sufficiently thick are slit down the middle, in order to admit the more unobstructed access of air and the evaporation of natural moisture. The cut and dried stalks are then laid down in regular order on the ground, the extremities of the leaves all pointing in the same direction, that they may be more easily gathered. This gathering is effected after a short exposure to the sun.

The next part of the process is the *curing* of the tobacco, which is carried on in large barns, whose sides are left partially open to allow a free circulation of air; and the internal area of the building, including the roof, is occupied by horizontal poles stretching across the barn in a parallel direction, and four feet asunder. These poles are connected together by cross-pieces called tobacco-sticks, upon which the leaves are hung in order to be cured. There are several stages of these poles and sticks, one above another, a perpendicular space of four feet being left between them. The plants are carried to the curing-house as soon as the leaves have lost so much of their rigidity and brittleness as to bear handling without breaking; and the operation of hanging them is then effected, by suspending the plants upon the sticks with the points of the leaves downwards, resting them either by the stalk of the lowest leaf, or by the slit which has been made in the stem. Each stick, after being loaded with plants placed four or five inches apart, is conveyed to the stage of poles to which it belongs; and the whole area of the barn becomes thus filled with the plants, no two touching each other.

The unassisted action of the atmosphere produces, in a general way, that effect for which this process is undergone; but it is sometimes necessary to have *small smothered fires* of rotten wood or bark in the barn, *to* counteract the effects of an unfavourable state of the weather. An exposure to the air for a period of about five weeks makes the leaves of tobacco elastic and tough, and slightly covered with a glossy kind of moisture. The tobacco is then said to be *in case*, and is taken down from the sticks, in order that the stalks may be separated from the leaves. The general plan is, for a party of negroes—men, women, and children—to sit in a circle on the floor of the tobacco-house, and to pull the leaves from the stalks, handing the former to two men placed in the centre, who distribute them into separate heaps according to their qualities. The lower or ground leaves, being generally soiled and torn, are separated from the rest; while of those produced in the higher part of the stalk, some are inferior to others; the whole are therefore distributed into three heaps.

At this stage in the proceedings it is necessary to mention a difference in the form in which tobacco is imported from the plantations. Our manufacturers distinguish between 'strip-leaf' and 'hand-work,' the former of which is the technical name for tobacco from which the stem of the leaf has been taken away before the latter is packed in the hogshead; whereas 'hand-work' is the name applied when the leaf is packed whole, stem and all. The stripping is effected by taking the leaf in one hand, and the extremity of the stem in the other, in such a manner as to tear them asunder in the direction of the fibre, a process requiring some degree of expertness: but whether the leaves are stripped or not, the subsequent processes are nearly the same. The leaves are tied up in small bundles by a bandage at their thicker end, a small leaf being employed for that purpose by twisting it round the others, and securing its end in a kind of knot. Each little bundle of those leaves from which the stalks have not been removed, is called a *hand*, and is, at the end where it is tied, somewhat thicker than a man's thumb, the length being from one to two feet, according to the kind of leaf. The 'strip-leaf' presents a slightly different appearance. All the bundles are then thrown together in heaps on a wooden platform, where they undergo the process of *sweating*, which is in its nature a slight degree of fermentation.

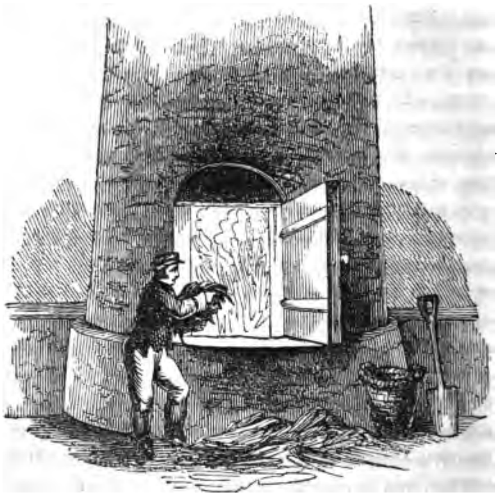
Packing for shipment is the next operation. The tobacco is packed in hogsheads, which are made perfectly dry for its reception; the tobacco is deposited in them, the little bundles or *hands* being ranged one by one parallel to each other across the hogshead, the points all in the same direction. The next course or layer is reversed, the points being in the opposite direction; and any small spaces that may occur are filled up with bundles of less size, so as to bring all to a level. When the hogshead is about one-quarter filled in this way, a powerful lever-press is applied to the surface of the tobacco, so as to reduce the thickness from about twelve inches to three. The lever is kept in this position for several hours, in order that the tobacco may become so completely consolidated that it will not spring up again when the pressure is removed. Fresh portions are then laid in the hogshead, and treated in a similar manner, until the whole space is filled with a dense and compact mass of tobacco-leaves. A hogshead, forty-eight inches in length, by thirty or thirty-two in diameter, will hold one thousand pounds weight of tobacco, when compressed in this way.

In these hogsheads the tobacco is imported, and is deposited in the government warehouses at London and elsewhere, until the duty is paid. In these tobacco warehouses at the London Docks may be seen ranges, tiers, or alleys of hogsheads, whose number is immense. Passage after passage occurs, each several hundred feet in length, and only wide enough to admit the necessary traffic: all parallel one to another, and all bordered on both sides with close and compact masses of hogsheads, generally two in height. The whole are under one roof, or rather one succession of roofs; and there are sometimes deposited there as many as twenty thousand hogsheads, averaging twelve hundred pounds of tobacco each.

Those who are unacquainted with Customs' and Excise regulations may perhaps not deem it immaterial to know why this enormous quantity of tobacco is kept in one place. The duty paid on every pound of tobacco is very large; but this duty is not demanded so long as the tobacco remains at the docks, or rather in the warehouses attached to the docks. As soon as it is landed at the docks from the ship and placed in the warehouses, it is considered to be *in bond*, under the care of the State, and cannot be removed thence till the duty is paid. If by any circumstance the whole or a portion of a hogshead of tobacco becomes injured, previous to its arrival at the docks, the owner would rather lose it altogether than pay the enormous duty on the damaged portion. Were the duty very small, it is possible that the damaged portion might be sold at a price which would more than cover the duty on it; but as it is, the duty is too high to permit of such a speculation. The State allows the damaged portion to be burned, without any duty having been paid on it. When a hogshead is to be opened, the head is knocked out, some of the staves loosened, and by a dexterous management the hogshead is taken completely off the tobacco, leaving the latter standing upright as a brown-coloured mass of tobacco-leaves, uncommonly dense and impenetrable. If, by the action of sea-water, bad packing, or any other cause, any of the mass has become injured, two men, provided with long cutting instruments, stand on opposite sides of the cylindrical mass of tobacco, and chop away all the injured part, by small bits at a time. The compression to which the tobacco has been subjected gives such a solidity and denseness to the mass, that very powerful blows are required to chip off the damaged surface, especially at the cylindrical parts, for there the cutting is effected crosswise to the direction of the stalk and leaf.

When the damaged portion is all cut away, the remainder is carefully weighed, in order that the amount of duty accruing to the State may be determined; and samples are then frequently taken from the hogshead, which suffice to effect a sale between the vender and the buyer of the hogshead of tobacco. The opened and loosened cask is next slipped over the mass of tobacco, and fastened as closely to it as is necessary, by the aid of the hoops; the head of the hogshead being also fixed in at the same time. The damaged tobacco is burned in a kiln at the Docks; by which all is consumed except an ash available as manure.

The leaf being brought to the manufacturer in hogsheads, he proceeds to give it one of the three forms in

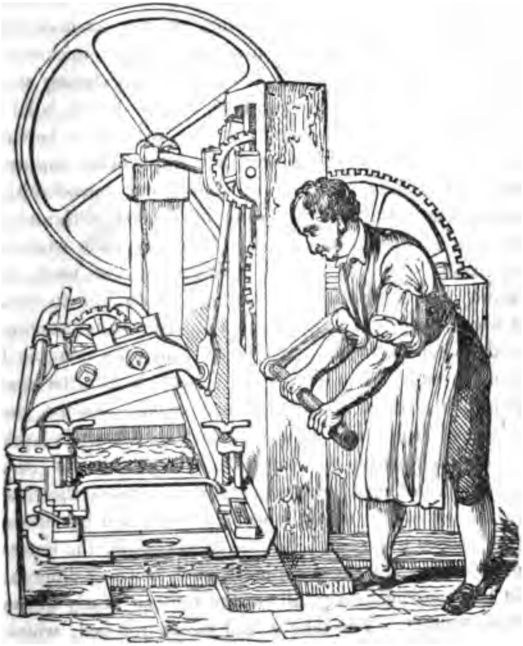


which it is used, *i.e.* tobacco, cigars, and snuff. Most persons are probably aware of the main points of difference between these three forms of the plant; but as all are not so, we may shortly state that the common smoking *tobacco* is the leaf, generally divested of the stalk, and also generally cut up into shreds or filaments; *cigars* are bundles of the tobacco-leaf, divested of the stalk, and wrapped up into the close and well-known form which those articles present; *snuff* is formed partly of the stalks of the leaves, and partly of the leaves themselves, cut and ground into the state of powder. These are the distinctive qualities in which the three *commercial* forms of the plant differ one from another; but each one of the three has many varieties, arising partly from differences in the quality of the original leaf, partly from the manner in which the leaf is cut, and partly also from the processes preparatory or subsequent to the cutting. It may likewise be here remarked that the manufacture of the leaf and stalk into the three forms in which the plant is used generally devolves upon three classes of persons. The same man who makes cigars does not generally prepare the tobacco which is smoked in pipes, while the grinding of snuff is a different occupation from either. The processes, too, are conducted in a somewhat different manner in different houses.

A hogshead of tobacco being opened, and ready for preparation, the plant is dug out piecemeal by the aid of an iron instrument. The bundles of leaves are, as we before observed, compressed so powerfully together, that they become almost one mass; and indeed without the aid of moisture it would be almost impossible to separate them. The heaps or pieces are sprinkled with water, a process technically termed 'liquoring;' by which the bundles of leaves may be separated one from another. If the tobacco is in the form called 'strip-leaf,' in which the stalk has been removed before the leaves were packed in the hogshead, each separate leaf or half-leaf becomes loosened from the others by the operation of liquoring; but if it be 'hand-work,' *i.e.* retaining the stalks, and bound up in bundles called 'hands,' the liquoring in the first place loosens the bundles one from another, and these being untied, the leaves themselves are separated.

The 'hand-work' must become 'strip-leaf' before the tobacco is in a fit state for use: or in other words, the stalk must be taken out, either at the plantations where the plant is grown, or in England after importation. The stripping or taking off of the stalk is effected generally by women or boys. The leaf is folded along the middle, and by means of a small instrument, and a dexterous manœuvre acquired only by practice, the stalk is stripped from the leaf, and laid on one side,—the leaf being laid in another place by itself. One particular kind of tobacco, however, known to consumers by the fanciful name of 'bird's-eye,' contains a portion of the stalk as well as leaf. To produce this form of the 'Virginian weed,' the various processes are performed on the leaf without the previous extraction of the stalk. The action of the cutting-machine, presently to be described, produces a large number of round, light, and exceedingly thin sections or slices of stalk, which become mixed up with the fine thread-like fibres into which the leaf itself is cut, and thus produce an appearance which has given rise to the name of this particular form of the plant.

The cutting of the leaves into those fine shreds which form the greater part of smoking-tobacco is not effected leaf by leaf; but a large number of leaves are pressed together in the form of a cake, and then cut. The leaves, after having been separated one from another, and



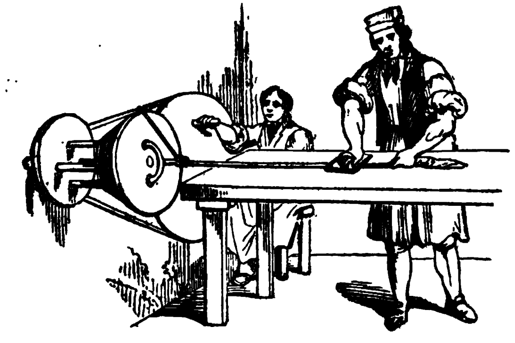
stripped of their stalks, are moistened to a certain degree, either by sprinkling or by immersion in a liquid prepared for that purpose. This process not only gives to the leaves a degree of moisture which enables them to cake well together, but also has an influence on their subsequent flavour, and is therefore of considerable importance in the manufacture.

The cutting-machine by which the thread-like fibres are produced is represented in page 139. The tobacco, after being very powerfully pressed, assumes the form of a flat cake, one-third of its former thickness. This cake, pressed as hard as a board, but clammy and wet from the previous sprinkling of the leaves, is laid upon the bed of the cutting-engine, in order to be cut into shreds. These engines, like most other engines used in manufactures, have undergone considerable changes as improvements became introduced. Originally tobacco used to be cut by means of a long knife worked by hand. After a time a hand-engine was used, in which the workmen had nothing to do but to turn a winch-handle, the arrangement of the machine serving both to cut the tobacco and to shift the cake along as it became cut. Then horses were used to turn the machine, instead of applying human labour. Lastly, the power of steam was applied, by which the whole work was brought within the scope of this moving power; the attendance of men being required only to place the cake in the engine, to attend it while at work, and to remove the tobacco when cut. But the hand-engine, the horse-engine, and the steam cutting-engine, however different in their moving-power, all cut the tobacco nearly in the ne manner. The cake is laid on an iron bed, which is susceptible of a slow progressive motion by means of a screw passing beneath it. This screw is connected at one end with a cog-wheel, in such a manner that while the machine is working, the bed on which the tobacco is laid is urged slowly forward. Another part of the mechanism gives motion to a sharp blade, rather longer than the width of the cake. This knife or blade has a reciprocating vertical motion, or rather a motion somewhat similar to that of a pair of nut-crackers, inasmuch as there is a hinge or fulcrum at one end. The cake is about two inches thick, and each action of the cutting-blade slices off a thin film from one end of the cake. As the cake itself is composed of a very large number of separate leaves of tobacco, it follows that each film or shaving taken from the edge, generally at right angles to the surface of the leaves, must be formed of separate pieces, in no case larger than filaments or fibres. The thickness of these fibres is regulated in a very ingenious manner. Immediately after the blade or knife has made one cut, the cake is moved forward a minute distance, so that the next following cut of the blade may be distant some small space from the former. It depends upon the number of cogs in the wheel at the end of the under-lying screw, whether this distance, and consequently the diameter of the fibres of tobacco, shall be greater or smaller.

When the cake is entirely cut up into shreds, the engine is stopped, and the cut tobacco, in a clotted and damp state, is taken up and put into a trough or case. A new cake is then adjusted to the bed of the engine, and the operations proceed as before.

The various kinds of tobacco ordinarily used for smoking owe their different qualities to many different circumstances; some depending on the kind of leaf, some on the colour of the leaf, some on the retention of the stalk, some on the extent to which the leaf is 'liquored,' and some on the relative fineness of the fibres into which it is cut. 'Bird's-eye' is, as before stated, produced by cutting up the stalk together with the leaf; a plan which is, we believe, never adopted with any other form of tobacco. That kind of tobacco called 'returns' is made of the lightest-coloured leaf, selected from the hogshead; and this light colour is preserved by caution in the consequent arrangements. A considerable quantity of water in the process of 'liquoring' has a tendency to darken the colour of the leaf, as has likewise an excessive amount of pressure when in the form of a cake; by using a small amount both of moisture and of pressure, therefore, lightness of the colour of 'returns' is preserved. The very strong kind of tobacco called 'shag,' which is used both for chewing and smoking, owes its quality to different circumstances, the first of which is the choice of the darkest-coloured leaves in the hogshead; in the subsequent processes the tobacco is well 'liquored,' and screwed down in the press with great force. This kind of tobacco is subdivided into two sorts, 'fine' and 'common,' the chief difference between which is in the diameter of the fibres into which the leaves are cut, the 'fine' being cut by the engine when the bed is pushed forward by a wheel having more cogs than for cutting the 'common' kind.

Many of the names by which tobacco is known were given from the names of the places whence it was brought, and from other circumstances having but little reference to the quality of the tobacco. 'Oroonoko,' a name given to one kind of tobacco, was probably derived from the South American river of that name. 'Knaster,' or 'Canaster,' was originally the name given in America to baskets of rushes or cane, in which they put the tobacco sent to Europe; and hence the designation of 'Kanaster tobacco' was given to the leaves imported in those baskets. At present the two kinds known by these respective names are manufactured from the best leaf, generally from Havannah. Oroonoko is cut finely, somewhat similar to fine 'shag,' but Knaster is much coarser. This forms the chief difference between the two kinds, the quality and preparation of the leaves being in other respects about equal.



The oddly-named 'pig-tail' tobacco is a rope or cord, about equal in diameter to the thicker end of a common tobacco-pipe, and of as great a length as the manufacturer may choose to make it. The manufacture of this article requires the simultaneous aid of a man and two boys. The bench employed is several yards in length, and at one end of it is a kind of spinning-wheel, which is kept in rotation by one of the boys. The other boy has spread out before him a supply of leaves, deprived of the stalks, and in a damp state. He opens the leaves one by one, and lays them down on the bench end to end. The man follows him and rolls up these successive leaves into the form of a cord, by a very peculiar motion of both his hands. The length of 'tail' which happens to have been made at any one moment is kept constantly rotating by the action of the wheel, and the man, adding leaf after leaf to it with the left hand, presses and rolls it by means of a palm of leather or wood held in his right. The manœuvre is so quick and so dexterous, that a spectator can hardly see where or how the leaf becomes absorbed into the 'tail,' and made part of its substance: it is one of those operations of which manufactures present such numerous examples, in which considerable skill is required for an apparently simple operation. As the tobacco is spun, it becomes wound off at the same time on a frame connected with the spinning-wheel. The pig-tail is afterwards wound or twisted up into a hard close ball, and has a black colour given to it by steeping in tobacco-water.

Of all the various ways in which tobacco is used in England, none has made a more striking advance within the last few years than *cigars*. However much this form of the plant may be used in Spain and in the tropical regions of America, it was till a few years ago scarcely known in England, except to the higher class of smokers; but its use is now very extensive.

The process of cigar-making, whether conducted abroad or at home, is pretty nearly the same. In the next two cuts we have represented a man preparing the leaves for the cigar-maker, and another making the cigars. The unstripped leaves, *i. e.* the leaves from which the stalks have not yet been removed, are placed in front of the first-mentioned workman; he takes up the leaves one by one, folds them, strips off the stalks by a quick and dexterous movement, throws the stalks on his right hand, and lays the stripped leaves smoothly on his left. He is on the left side of the cigar-maker, to whom he hands up the leaves as fast as they are wanted.

The cigar-maker is seated on a low stool in front of a low workbench, which has raised ledges on three of its sides, but is open at the side next the workman. He takes a leaf of tobacco, spreads it out smoothly before

him on the bench, and cuts it to a form somewhat like that of one of the gores or stripes of a balloon. He then takes up a few fragments of tobacco-leaf, consisting of various small cuttings, lays them on the spread leaf, and rolls them up into a form nearly resembling that of a cigar. He next places this cigar against a gauge or guide, formed of a piece of iron, and cuts it to a given length. Finally, he lays a narrow strip of leaf on the bench, and rolls the cigar spirally in it, twisting one end to prevent the leaf from becoming loosened. All this is done with great rapidity, a few seconds only being required for the making of one cigar. When the cigars are made, they are dried in different ways, according to the time when they are wanted for sale. The rate of duty on foreign cigars, as well as on all kinds of tobacco manufactured abroad, is so enormous (nine shillings per pound—probably sixteen or eighteen times the real value of the leaf itself), that the quantity imported from abroad is very small compared with that of tobacco in the leaf. Only one hundred and fifty thousand pounds weight were entered for home consumption two or three years ago, although the unmanufactured tobacco amounted to sixteen millions of pounds. This rate of duty has therefore given rise to an extensive home-manufacture of cigars.

The third form in which the plant is used is that of *snuff*. This article has been the theme of as many grave accusations as tobacco in the form for smoking: but the grave accusations have been as fruitless in the one case as the other. Some have treated the matter in a medical point of view; others, in reference to the welfare of the purse; while Lord Stanhope has taken the following curious statistical estimate of the matter:—"Every professed, inveterate, and incurable snuff-taker, at a moderate computation, takes one pinch in ten minutes. Every pinch, with the agreeable ceremony of blowing and wiping the nose, and other incidental circumstances, consumes a minute and a half. One minute and a half out of every ten, allowing sixteen hours to a snuff-taking day, amounts to two hours and twenty-four minutes out of every natural day, or one day out of every ten. One day out of every ten amounts to thirty-six days and a half in a year. Hence, if we suppose the practice to be persisted in for forty years, two entire years of the snuff-taker's life will be dedicated to tickling his nose, and two more to blowing it. The expense of snuff, snuff-boxes, and handkerchiefs will be the subject of a second essay, in which it will appear that this luxury encroaches as much on the income of the snuff-taker as it does on his time; and that by a proper application of the time and money thus lost to the public, a fund might be constituted for the discharge of the national debt."

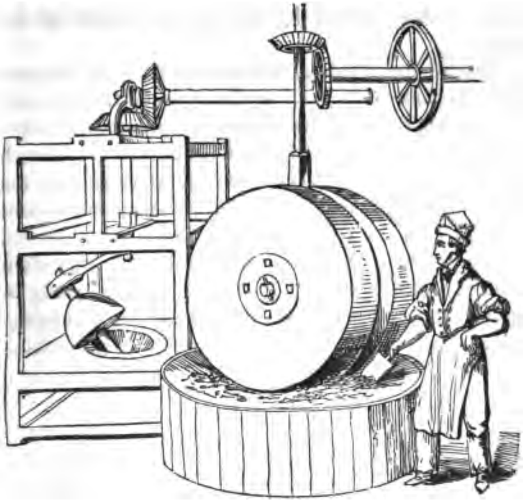
Snuff is made from stalks alone, from leaf alone, or from leaf mixed with stalk—circumstances which render the whole of the imported leaf valuable: in every case a greater amount of care is required in the preparation of snuff than of tobacco. The various qualities of snuff are due to a great variety of circumstances, principally under the control of the manufacturer. The purest kind of snuff is that which goes by the name of 'Scotch,' which is either made entirely of stalks, or of stalks mixed with a small proportion of leaf; in either case there is very little 'liquoring' applied to the tobacco, as that would darken the colour of the snuff. There are many kinds of snuff called 'high-dried,' such as 'Welsh' and Lundyfoot' (the latter being named after a celebrated maker). These owe their qualities chiefly to the circumstance that they are dried so much as to acquire a slight flavour of scorching.

The snuffs called 'rappee,' of which there are two kinds, 'brown' and 'black,' are made chiefly from leaf, to which is added the 'smalls,' or broken fibres of tobacco, which are too small to be smoked conveniently in a pipe. The dark colour is principally produced by wetting the powdered tobacco in a bin or box, and allowing it to remain for a considerable time, turned occasionally with a shovel; during which time it undergoes a slight degree of fermentation, which darkens the colour.

The original quality of the leaf is as much attended to as the subsequent processes. Scotch snuff is made principally from the stalks of light dry leaves; whereas 'rappee' and the darker snuffs are made from the darker and ranker leaves. A process of *scenting*, too, has great influence on the flavour of the snuff, since the manufacturer can introduce any kind of scent which he thinks may please his customers. Thus, 'Prince's mixture,' among the low-priced snuffs, and the interminable varieties of 'fancy snuffs,' owe no small part of their flavour to the kinds of scent introduced. Other kinds, however, such as 'high-dried,' 'Welsh,' 'Lundyfoot,' &c., are chiefly dependent on the peculiar circumstances under which they are dried. In relation to the last-named snuff, Mr. Barlow states—"The celebrated Lundyfoot snuff derives its particular flavour chiefly from having the fermentation carried to a very high pitch before the batch is turned; and it is said that its first discovery was owing to the neglect of the man attending upon the batches, and who, by getting drunk, made his master's fortune. Another story also prevails with respect to the discovery of this snuff, so much esteemed by inveterate snuff-takers, which attributes it to an accidental fire, which, by scorching some hogsheads of tobacco, gave them a peculiar flavour when manufactured. This story is, however, evidently without foundation, as the snuff manufactured by Lundyfoot still continues to retain a peculiar flavour which cannot be imitated by other manufacturers; a circumstance which is not likely to continue if the effect simply depended upon the degree of drying."

It is a curious circumstance, and one little suspected by those who are in the habit of using snuff, that almost the whole of that which is sold in the metropolis, either wholesale or retail, is ground in or near the town of Mitcham in Surrey; owing to the excellent water-power afforded by the river Wandle, which passes through the town. Many manufactories on the Wandle derive their mechanical power from water-wheels, which were almost invaluable before the use of steam became prevalent. The advantage of employing a particular class of persons for grinding snuffs, instead of each manufacturer grinding his own, is easily understood. Few manufacturers dispose of enough snuff to keep a grinding-mill constantly employed; and under such circumstances it is generally cheaper to obtain the aid of another person whose premises and arrangements are devoted wholly to that occupation. Such is the case with regard to the snuff-mills on the Wandle. There are several of these establishments to which the London manufacturers send their snuff in a certain stage of preparation.

The mills are provided with two different kinds of grinding-machines, such as are represented on a small scale in the annexed cut. In one of them a pair of cylindrical stones, several feet in diameter and a foot or more in thickness, are set up on edge on a slab or bed beneath, and have then a two-fold motion given to them resembling that of the wheel of a carriage which is going round in a small circle. By means of a horizontal axis passing through the centre of the stones, the stones wheel along the surface of the bed; and by giving to



the axis itself a motion round another but vertical axis, the stones are carried round in a small circle. The snuff to be ground is laid on the bed or support, and the broad edge of the heavy stone passes repeatedly over it, by which the particles are reduced to powder.

In the other form of grinding-mill, the snuff is put into a kind of cell or mortar, in which it is ground by a pestle moved in a singular manner. The pestle is connected with a set of jointed arms or levers, so adjusted one to another as to give to the pestle a motion best calculated to effect the grinding of the snuff. Every establishment for grinding snuff contains a considerable number of both these machines; since some kinds of snuff are best ground by the one, and others by the other.

Beyond the grinding, and a preparatory drying, nothing is done to the snuff at the snuff-mills. The proprietor brings it to a certain stage of preparation before it is sent to the mill, and in most cases passes it through some finishing operations after it is brought from the mill. The high-dried snuffs, such as Lundyfoot, Welsh, Scotch, &c., are sometimes made from stalks, which, before grinding, are cut into fine shreds; but very often the entire stalk is dried so intensely that it may easily be ground to powder without the preparatory shredding. In such case the lightest and finest stalks are presented.

## CHAPTER VIII.

### HAT-MAKING, BEAVER AND SILK; STRAW PLAIT.

WE shall now, before concluding this volume, find a corner for a few details relating to two departments of clothing manufactures, viz., that of *hats*, and that of *leather*.

The former of these relates to an article of dress which has suffered singular changes at different times. Philip Stubbs, a writer of the Elizabethan age, published, in 1585, his 'Anatomie of Abuses,' in which, among other things, he thus speaks of the then fashionable hats:—"Sometimes they use them sharp on the crown, peaking up like the spear or shaft of a steeple, standing a quarter of a yard above the crown of their heads, some more, some less, as please the fancies of their inconstant minds. Some others are flat and broad on the crown, like the battlements of a house. Another sort have round crowns, sometimes with one kind of band, sometimes with another, now black, now white, now russet, now red, now green, now yellow; now this, now that, never content with one colour or fashion two days to an end. And thus in vanity they spend the Lord's treasure, consuming their golden years and silver days in wickedness and sin." But the material pleases him as little as the form and colour:—"And as the fashions be rare and strange, so is the stuff whereof their hats be made divers also; for some are of silk, some of velvet, some of taffetie, some of sarcenet, some of wool; and, which is more curious, some of a certain kind of fine hair. These they call *Bever Hats*, of twenty, thirty, or forty shillings price, fetched from beyond the seas, from whence a great sort of other vanities do come beside."

The general tenor of the change which has taken place since Stubbs's time, is the establishment, almost exclusively, of fur, wool, and silk plush, as the material for hats, either in respect to the foundation or the covering. Many a person has probably put to himself the question—"How is a beaver hat made?" One would think it is cast in a mould; another, that the beaver's fur, skin and all, is stiffened and shaped; a third, that the fur is in some way woven into a kind of cloth, and put on a stiff foundation; but very few would have an idea of the beautiful process of *felting*, which is the groundwork of the whole theory of hat-making. A beaver hat consists mainly of two parts—the *body* and the *covering;* the former of which is made of fine wool and coarse fur, mixed, felted, stiffened, and shaped; and the latter of beaver fur, made to adhere to the body by the process of felting. Wool and fur constitute therefore the main ingredients employed. For hats of inferior quality, coarse wool is employed for the body, and coarser fur, or sometimes fine wool, for the covering.

The wool is brought to the hat-factories in a dirty and greasy state, retaining much of the moisture derived from the animal. It is carried to a washing-house, where it is soaked and washed, until the greasiness is removed, and is then subjected to the action of a screw-press, whereby all the water is expelled, and the wool left in a clean state. From the washing-house the wool is conveyed to a drying-room; and, when required for use, it undergoes the process of *carding*, by means of a machine which combs out the fibres of wool, and presents them in a light and tolerably disentangled state. The wool is then ready for the hatter; and we will trace the preparation of the fur up to the same point.

The term *fur*, in a general sense, refers to the hairy coating of such animals as the beaver, bear, marten, minx, hare, and rabbit. The skins of these animals, when merely dried after being stripped from the body, are called *peltry;* when the skin of the inner side has been converted into a sort of leather, by a peculiar process of tanning, the skins obtain the name of *furs*, in a restricted sense; and the term is still more restricted when applied to the hairy coating cut from the skin, and presented in the form of delicate filaments.

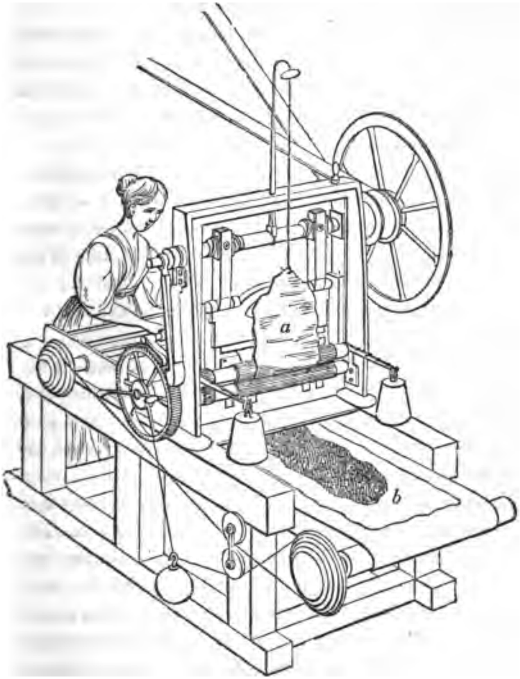
Now it is in the last-named form that fur is useful to the hatter; and the furs to which he gives the preference are those of the beaver, the musquash, the neutria, the hare, and the rabbit, of which the first is by far the most valuable. The beaver inhabits the districts of North-West America, where its peculiar habits of life have given rise to many marvellous tales, the truth of which is now more than doubted. The skins, as received at the factory from the Hudson's Bay Company, are tolerably flat and stiff, measuring, generally, about three feet by two. The hairy surface is of a brownish colour, but is not that to which the hatter attaches value; for this animal has two kinds of hair on its skin, the innermost of which is short, implicated, and as fine as down, and the outermost thicker, longer, and more sparing. Of the separation of these two kinds we shall speak presently.

*Neutria* is the fur of a small animal called the *coypou*, the *quoiya*, or the *Myopotamus Bonariensis*, found in various parts of South America. The long or coarse hairs are generally of a reddish colour; and the inner or soft hairs, brownish ash colour. It was not until about thirty years ago that hatters, influenced by the high price of beaver fur (which within a century has risen from 20*s*. to 80*s*. per pound), began to use neutria fur; but since that time the employment of them has become so extensive, that one million neutria skins have sometimes been imported in one year.

The *Musquash*, or *Mus Zibethicus*, is a North American animal, about the size of the common rabbit, and covered, like the beaver and the coypou, with two kinds of hair or fur, having different degrees of fineness. The name *musk rat* is sometimes given to this animal, on account of its secretion of a peculiar fluid having the odour of musk. The fur of *hares* and *rabbits* is so well known as to render few words of description necessary. The rabbits fed on the wolds of Yorkshire are said to yield fur much exceeding in value that of the rabbits bred near London, by reason of the superior length and strength of the hairy filaments.

The skins or pelts are rather greasy and dirty, and are therefore, when about to be used in hat-making, cleansed with soap and water. When dried and required for further processes, they are carried to the 'pulling-room,' where a number of women, seated on stools, are employed in pulling out the coarse outer hairs from the skins: these coarse hairs are utterly useless to the hatter, and, if preserved at all, are sold for stuffing cushions and such-like purposes. Each woman lays a pelt on her lap, or on a low bench, and, by means of a knife acting against the thumb, tears out the larger hairs, her fingers and thumb being guarded by a stout leather shield.

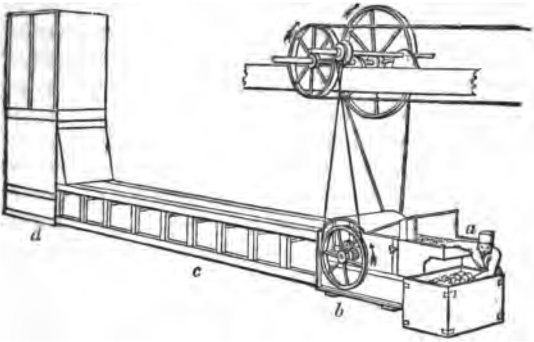
The pelts next pass under the action of a beautiful piece of mechanism called a 'cropping-machine,' by



Cropping-Machine. *a*, the skin, passing between rollers, after the fur has been cut from it; *b*, the fur deposited in a light layer on an endless cloth.

which the fur is taken off. A long, broad, and sharp blade, having the edge downwards, works very rapidly, with a chopping action; and the pelt being introduced between the blade and a support beneath, the fur is cut from it with a precision that nothing can exceed. The impression on the mind of a visitor is that the pelt must inevitably be chopped to shreds, but, by some admirable adjustment of mechanism, the fur is removed without the skin being cut. The female who attends the machine puts it in or out of work when required, guides the pelt through it, collects the filaments of fur, &c. Such outer fragments or small pieces of the pelt as do not lose their fur by the action of the machine, are laid on a table, and women, by the aid of small instruments shaped somewhat like a cheese-cutter, remove the remaining fur. The denuded skins are useless to the hatter, and are sold at a small price to size-makers in the north of England.

We have said that the women in the 'pulling-room' cut, tear, or pull out the long coarse hairs from the pelts, and that these hairs are useless to the hatter. But it is impossible completely to separate the coarse from the fine fur by this means; and, therefore, the fur, when cropped from the pelt by the machines, is conveyed to the 'blowing-room,' finally to effect the separation. The 'blowing-machines' (of which one is sketched in the cut) act as follows:—A quantity of beaver or other fur is introduced at one end, near a compartment in which a vane or fly is revolving with a velocity of nearly two thousand rotations in a minute. We all know that a body in motion gives rise to a wind or draught; and when the motion is so rapid as is here indicated the current be-

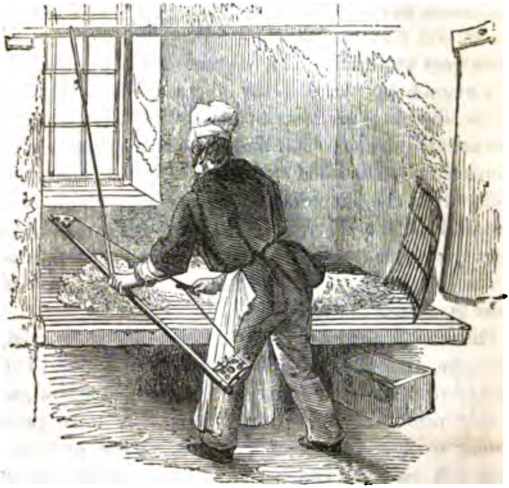


Blowing-Engine. *a*, spot on which the fur is placed; *b*, box containing the revolving fan; *c*, hollow trunk through which the fur is blown; *d*, receptacle where the finer fur is deposited.

comes very powerful. This current of air propels the fur along a hollow trunk to the other end of the machine, and, in so doing, produces an effect which is as remarkable as it is valuable. All the coarse and comparatively valueless fur is deposited on a cloth stretched along the trunk, while the more delicate filaments are blown to a receptacle at the other end. Nothing but a very ingenious arrangement of mechanism could produce a separation so complete as is here effected; but the principle of action is not difficult to understand.

The wool and the fur being thus separately prepared, arrangements are now made for combining them. The 'body,' or 'foundation,' of a good beaver hat is now generally made of eight parts rabbits' fur, three parts Saxony wool, and one part of llama, vicunia, or 'red' wool. A sufficient quantity of these for one hat (about

2½ ounces) is weighed out and placed in the hands of the 'bower.' The bow is an ashen staff, from five to seven feet in length, having a strong cord of catgut stretched over bridges at the two ends; it is suspended in the middle by a string from the ceiling, whereby it hangs nearly on a level with the work-bench. The wool and coarse fur, first separately and afterwards together, are laid on the bench, and the bower, grasping the staff of the bow with his left hand, and plucking the cord with his right by means of a small piece of wood, causes the cord to vibrate rapidly against the wool and fur. By repeating this process for a certain time, all the original clots or assemblages of filaments are perfectly opened



and dilated, and the fibres, flying upwards when struck, are by the dexterity of the workman made to fall in nearly equable thickness on the bench, presenting a very light and soft layer of material. Simple as this operation appears to a stranger, years of practice are required for the attainment of proficiency in it.

The point in the routine of processes at which we have now arrived requires a brief consideration of the operation of felting, on which the whole manufacture of a beaver hat depends. Felting is a process whereby animal fibres are made to cohere and to form a kind of cloth, without the aid of weaving, plaiting, knitting, sewing, or any analogous processes—warmth, moisture, and friction being the means by which it is effected. There is reason to believe that the process of felting was known in early times, and that the tents of the Tartars, as well as some articles of clothing, were produced by these means; but the evidence on this point is rather indistinct. At what time felted wool was first employed for making hats it would be difficult now to say; but the philosophy of felting was not understood until the microscope was applied to the examination of animal fibres. It was then found that the fibre, whether of wool or fur, is surrounded by a vast number of minute teeth projecting obliquely from the central stem. As these teeth are very sharp and are turned in one direction, they present an obstacle to the motion of the fibre in that direction, but enable it

Microscopic view of a fibre of beaver fur.

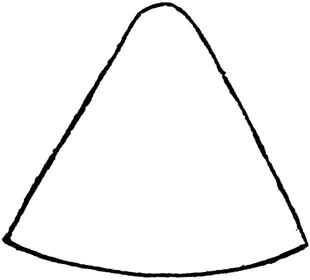
to glide easily in the opposite one; just as an ear of barley, when placed stalk uppermost within the cuff of the coat-sleeve, will soon work its way up to the shoulder by the motion of the arm. In some woolly fibres the irregularities appear like concentric cups, rather than sharp teeth.

When a heap of such fibres is rubbed and pressed, and the fibres made to curl slightly by the action of warmth and moisture, they twist around each other, and the teeth interlace so tightly as not to separate. So complete, indeed, is the entanglement of fibres thus produced, that a coat made from cloth manufactured solely by the felting process has been known to last in wear ten years.

Such being the origin and nature of the felting process, the operations of the workmen become intelligible. The bowed materials for one hat are divided into two portions, each of which is separately pressed with a light wicker frame, and afterwards with a piece of oil-cloth or leather, called a 'hardening-skin,' until, by the pressure of the hands backwards and forwards all over the skin, the fibres are brought closer together, the points of contact multiplied, the serrations made to link together, and a slightly coherent fabric formed. These two halves, or 'batts,' are then formed into a hollow cap by a singular contrivance. One of the 'batts,' nearly triangular in shape, and measuring about half a yard in each direction, being laid flat, a triangular piece of paper, smaller in size than the batt, is laid upon it, and the edges of the batt, being folded over the paper, meet at the upper surface, and thus form a complete envelope to the paper. The two meeting edges are soon made to combine by gentle pressure and friction, and the other batt is laid over the first in a similar way, but having the meeting edges on the opposite side of the paper. The doubled layer, with the enclosed paper, are then folded up in a damp cloth and worked by hand; the workman pressing and bending, rolling and unrolling until the fibres of the inner layer have incorporated with those of the outer. It is evident that, were there not a piece of paper interposed, the whole of the fibres would be worked together into a mass by the opposite sides felting together; but the paper maintains a vacancy within, and when withdrawn at the edge which is to form the opening of the cap, it leaves the felted material in such a form as to constitute, when stretched open, a hollow cone.

The cap is then taken to a large kettle or boiler, open at the top, having a fire beneath it, and eight planks ascending obliquely from the margin, so as to form a sort of octagonal work-bench, five or six feet in diameter, at which eight men may work. The planks are made of lead near the kettle, and of mahogany at the outer part, and at each plank a workman operates on a conical cap, until the process of felting or 'planking' is completed. The 'kettle' contains hot water slightly acidulated with sulphuric acid; and, as far as words can do so, the following may convey an idea of the process:—The cap is dipped into the hot liquor; laid on one of the planks, and subjected to a long felting process; it is rolled and unrolled, twisted, pressed, and rubbed with a piece of leather or wood tied to the palm of the workman's hand, and rolled with a rolling-pin. From time to time the cap is examined, to ascertain whether the thickness of the material is sufficient in every part; and if any defective places appear, they are wetted with a brush dipped in the hot liquor, and a few additional fibres are worked in. Considerable skill is required in order to preserve such an additional thickness of material at one part as shall suffice for the brim of the hat. When this felting process has been continued for about two hours, it is found that the heat, moisture, pressure, and friction have reduced the cap to one half of its former dimensions, the thickness being increased in a proportionate degree.

The felted or 'planked' cap is then taken to a stove-room; and when dried, it presents the appearance of a fine, stout, and very strong kerseymere, having a drab or greyish colour. It is still merely a drab-coloured, flexible, conical cap, about fifteen inches wide and fourteen high, and without a particle of beaver on its surface. The surface, colour, and form are, however, now about to be changed, in the order here indicated.



In the first place, the cap is taken to the 'water-proofing' room, where the odour of gums, resins, and spirits gives some intimation of the materials employed. Gum-lac, gum-sandarach, gum-mastic, resin, frankincense, copal, caoutchouc, spirits of wine, and spirits of turpentine, are the ingredients (all of a very inflammable nature) of which the water-proofing composition is made. This is laid on the cap by means of a brush, and the workman exercises his skill in regulating the quantity at different parts, since the strength of the future brim and crown depends much on this process.

After another 'stoving,' by which the spirit is evaporated, the exterior of the cap is scoured with a weak alkali, to remove a portion of the gummy coating, and thereby enable the beaver fur afterwards to cling to the woolly fibres of the cap.

Now, for the first time, we have to direct our attention to the fine beaver fur, the purchase and preparation of which are so costly. The washing, plucking, cropping, and blowing have been already described; and we have seen the fibres of fur divided into two qualities, of which the finer is that to which the hatter attaches value. This finer quality being bowed very carefully by a smaller bow than that employed for wool, is spread out into a layer, and by means of the 'hardening-skin' is pressed and worked into a very delicate and light felt, just coherent enough to hold together. This layer, which is called a 'ruffing,' or 'roughing,' is a little larger than the cap body; and to unite the two, another visit to the 'kettle' is necessary. The cap being softened by submersion in the hot liquor, the 'ruffing' is laid on it, and patted down with a wet brush, a narrow strip of beaver being laid round the inside of the cap, to form the underside of the future brim. The beavered

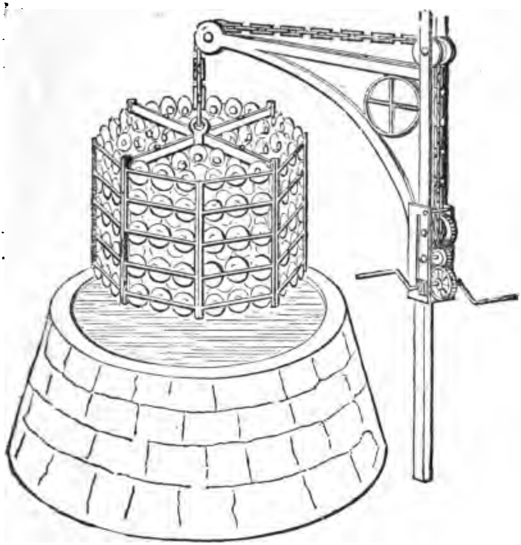
cap is then wrapped in a woollen cloth, submersed frequently in the hot liquor, and rolled on the plank for the space of two hours. The effect of this rubbing and rolling is very curious, and may be illustrated in a simple manner :—if a few fibres of beaver fur be laid on a piece of broad-cloth, covered with tissue-paper, and rubbed gently with the finger, they will penetrate through the cloth and appear at the opposite side. So, likewise, in the process of 'ruffing,' each fibre of fur is set in motion from root to point, and enters the substance of the felt cap. The hairs proceed in a pretty straight course, and just enter the felt, with the substance of which they form an intimate union. But if the rolling and pressing were continued too long, the hairs would actually pass through the felt and be seen on the inside instead of the out; the workman, therefore, exercises his judgment in continuing the process only so long as is sufficient to secure the hairs in the felt firm enough to bear the action of the hat-brush in after-days. Eighty or a hundred years ago, when beaver fur was cheap, an "old English gentleman" was wont to have his hat so well beavered, that as much nap felted through it to the inside as remained on the exterior; and when the hat showed symptoms of decay and old age, it was sent to the maker, who turned it inside out, and gave it nearly the pristine freshness of a newly-made hat.

At length the cap is to assume somewhat the shape of a hat, before it finally leaves the 'kettle.' The workman first turns up the edge of the cap to the depth of about an inch and a half; and then draws the peak of the cap back through the centre or axis, so far as not to

take out the first fold, but to produce an inner fold of the same depth. The point being turned back again, produces a third fold; and thus the workman proceeds, till the whole has acquired the appearance of a flattish circular piece, consisting of a number of concentric folds or rings, with the peak in the centre. This is laid on the 'plank,' where the workman, keeping the substance hot and wet, pulls, presses, and rubs the centre until he has formed a smooth flat portion equal to the intended crown of the hat. He then takes a cylindrical block, on the flat end of which he applies the flattened central portion of the felt; and by forcing a string down the curved sides of the block, he causes the surrounding portion of the felt to assume the figure of the block. The part which is to form the brim now appears as a puckered appendage round the edge of the hat; but this puckered edge is soon brought to a tolerably flat shape by pulling and pressing.

The hat, when dried, is placed in the hands of the 'shearer,' who raises and opens the nap of the hats, by means of a peculiar sort of comb; and then shears the hairs to any required length. Connoisseurs in these matters are learned as to the respective merits of 'short naps' and 'long naps;' and by the shearer's dexterity these are regulated. The visitor recognises nothing difficult in this operation; yet years of practice are necessary for the attainment of skill therein; since the workman determines the length of the nap by the peculiar position in which the long light shears are held. A nap or pile as fine as that of velvet can be produced by this operation.

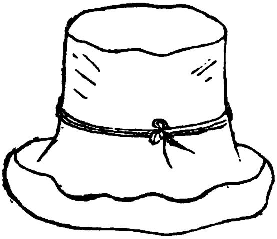
Then comes the *dyeing* of the hats. The dyeing in-

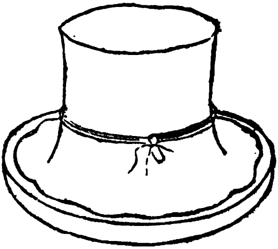


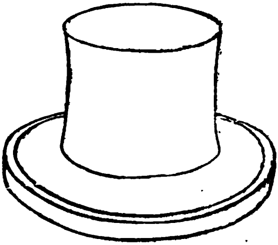
gredients are logwood and some metallic salts, boiled in certain proportions in soft water. The logwood is imported from Campeachy in logs five or six feet long, and from five to ten inches thick; and these are cut up into shreds. The ingredients being ready, and contained in a large cauldron, a number of hats are fixed upon blocks, and the blocks, by means of a hole at one end of each, are fixed to brass pegs inserted in a large skeleton frame; so that the hats shall not touch each other. The frame is then lowered into the cauldron, and turned in such a manner as to allow all the hats to be submerged in the dye; after which the frame is hauled up, and the hats allowed to drain for thirty or forty minutes. This alternate submersion and partial drying is repeated twelve or fifteen times, until every fibre of the hat,—felt as well as nap,—is thoroughly dyed. This is followed by soaking and washing, which frees the surface from impurities; and the hat is then again 'stoved.' A few subsequent processes remove certain irregularities of shape, which the hat has acquired by repeated submersions in the dye-liquor; and it is then given to the 'finisher.'

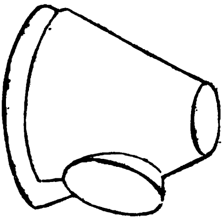
A boiler is so arranged as to yield a jet of steam, over which the hat is held until thoroughly softened; and having a block shaped in every part nearly as the hat is intended to be, the 'finisher' pulls, rubs, and presses the hat, until it assumes the form of the block; after which the nap is stretched, turned in any required direction, and smoothed, by various sets of brushes, small cushions of velvet, and heated irons. The adjoining cuts show three successive stages in the shaping of the hats, from the first rough 'blocking' to the production of a flat and smooth-edged brim while on the finishing-block; likewise a beaver bonnet on the block by which it is shaped.

The hats are then placed in the hands of females, by whom they are 'trimmed,' that is, provided with the lining, the leather, the binding, &c. After this, a further employment for females is found thus:—However carefully the process of 'blowing' may be performed, in order to separate the coarse fibres of the fur from the more delicate, there are always a few of the former left mingled with the latter; and these are worked up during









the whole of the subsequent processes. Women are employed, therefore, after the hats have left the 'finishers,' in picking out, with small tweezers, such defective fibres as may present themselves at the surface of the hats.

Lastly, the hat is placed in the hands of a workman whose employment requires an accurate eye, and a fertile taste in matters of shape and form: this is the 'shaper.' He has to study the style and fashion of the day, as well as the wishes of individual purchasers, by giving to the brim of the hat such curvatures in various directions as may be needed. Simple as this may appear, the workman who possesses the requisite skill can command a high rate of wages.

## *Silk Hats.*

A few lines may now be bestowed upon the production of 'silk hats,' as distinguished from those made of beaver-fur.

As the number of beavers caught annually in America has greatly declined, the price of beaver-fur has of late years increased; and this circumstance has led to the production of a kind of hat which presents some resemblance to beaver, and yet may be produced at a low rate. This is the *silk* hat, the manufacture of which has gone through several stages of improvement, by which even an humble 'gossamer' now presents a neat and glossy exterior.

Silk is wholly incapable of the process of felting, and therefore cannot be employed in the same manner as fur and wool. The body of the silk hat is made either of coarse felted wool, or of some light material such as willow or stiffened cambric; and on this is placed a covering or hood of silk plush, sewn to the proper size for the hat. The plush for the larger number of silk hats is woven in Lancashire; but for 'Paris hats,' as they are called, it is woven in France.

The bodies are made in a very rough way, by shaping the willow, cotton, or felted wool round blocks, and using a substance of extra thickness for the brim. A varnish cement is used to join the various parts; and a resinous stiffening composition is laid over the outer surface. Some time before the plush hood is laid on, the body is coated with a peculiar varnish, which, being softened by a heated iron after the hood is laid in its proper position, causes the plush to adhere to the foundation. This process is the most difficult in the silk-hat manufacture; for not only must the plush be made to adhere in every part, but the seam or joining up the side of the hat must be made as little visible as possible. No sewing is here employed; but the two meeting edges are brought precisely together, pressed down with a heated iron, and the silk shag brushed over the joint.

The minuter details of the silk-hat department we must pass over; for, so far as they differ from beaver hatting, they are of much less interest. Beaver hatters look down with some little scorn on the operations of silk hatting; and certainly, so far as regards manipulative skill acquired by long practice, the former branch of handicraft is by far the most remarkable; but still the silk hatter appeals with such moderation to the purse of the purchaser, that we cannot afford to lose sight of him.

There are a few other kinds of hats besides these of fur and of silk. For instance, there are common black glazed japan hats, such as are worn by sailors and persons much exposed to the weather. The bodies of these hats are made of common felted wool, and the outer covering is a thick coating of black varnish or japan, presenting a glossy surface: a high temperature is required for this japanning.

Another kind is that of seal-skin and other skin or fur caps. In these, unlike beaver hats, the fur is not cut from the pelt and then felted; but the pelt, with the fur remaining on it, is dressed into leather, and is cut up into such pieces as may, by subsequent processes, be formed into caps of various shapes. Another department of the manufacture is that of cloth caps of various kinds. This, generally speaking, is effected by needlework, and wholly differs from the processes of hat-making.

## *Straw-plait.*

There is a variety of hat (or bonnet) which deserves notice here, on account of the peculiarities connected with its manufacture; viz., that made of *straw-plait*. Extensive as is this manufacture, it is not supposed to have been carried on as a separate branch of trade until within seventy or eighty years; for the wives and daughters of the farmers used to plait straw for making their own bonnets. A notice of the straw-plait manufacture divides itself into two varieties—British and foreign; and for a few details respecting these we shall be indebted to M'Culloch.

The district of England in which straw-plait is made comprises the counties of Bedford, Hertford, Buckingham, and parts of Essex and Suffolk, being the counties most favourable for the production of wheat-straw. During the late war, the importation of straw-hats from Leghorn having in a great measure ceased, an extraordinary degree of encouragement was given to the domestic manufacture in England, and a proportional degree of comfort was derived by the agricultural labourers in these places, by whose wives and children it was principally followed. This activity led to competition; and the competition led to improvements in the growth and selection of the straw, and in the splitting, finishing, and bleaching. But when the conclusion of the war led to the importation of Leghorn hats, their fineness, colour, and durability speedily gave them a preference over the home manufacture, which thenceforth declined. With the view of improving the condition of the straw-plaiters, the Society of Arts offered premiums for the successful application of some of our native grasses, or straw other than the wheat-straw in general use; and for improvements in plaiting, finishing, and bleaching. The result of these offers was, that although the English straws, from the brittleness of their stems and the inequality of their colour, were not able to compete with the Leghorn, yet, by imitating and introducing among the English plaiters the Italian mode of plaiting and the Italian straw, it has been found practicable to establish an intermediate system by applying English labour to Italian straw. The duty on the import of Leghorn hats was 5*s.* 8*d.* or 11*s.* 4*d.* each, according to the size; and of the Italian plait, 17*s.* per pound; whereas the straw paid but a mere nominal duty of one penny per cwt.; and thus the English plaiters were able to produce, from Leghorn straw, hats at a greatly lower price than the real Leghorn hat could possibly be sold for in England.

Of this branch of industry it has been observed:—"There is, perhaps, no manufacture more deserving of encouragement and sympathy than that of straw-plait, as it is quite independent of machinery, and is a domestic and healthful employment, affording subsistence to great numbers of the families of agricultural labourers, who without this resource would be reduced to parish relief. By the estimate of an intelligent individual, intimately acquainted with the manufacture, it is considered that every score (or twenty yards) of plait consumes a pound of straw in the state in which it is bought of the farmer;

that, at an average, every plaiter makes fifteen yards per day; that in the counties of Hertford, Bedford, and Bucks there are, at an average, ten thousand scores brought to market every day, to make which thirteen thousand persons, women and children, must be employed. In Essex and Suffolk it is estimated that two thousand scores are the daily produce, to make which about three thousand persons are employed: and about four thousand persons more must be employed to convert these quantities into bonnets. Including other places where the manufacture is carried on in England, there are, perhaps, in all about thirty thousand persons engaged in it."

About twenty years ago a Scotch firm established straw-plaiting in the Orkney Isles, and adopted rye-straw as the material; and at first there seemed some prospect of success; but it does not appear that the competition of foreign-grown straw could be successfully met.

There are several descriptions of plait made in England—such as the 'whole Dunstable,' the 'split straw,' the 'patent Dunstable,' the 'Devonshire,' the 'Luton,' the 'Bedford Leghorn,' the 'Italian,' the 'backbone,' the 'lustre,' the 'wave,' the 'diamond,' &c.; differing from one another in the straws being whole or split, in the thickness of the straws, in the number of them plaited together, and in other points.

In Italy this manufacture is principally followed in the neighbourhood of Florence, Pisa, Sienna, and the Val d'Arno, in the duchy of Tuscany; and it is also established at Venice and other places. It is purely a domestic manufacture, as in England, and the produce is collected by dealers who go round the country. It has been estimated that about thirty thousand persons are engaged in the manufacture. The straw employed is cultivated solely for this purpose, and is a variety of bearded wheat somewhat similar to that grown in the Vale of Evesham. After undergoing a preparatory process, the upper parts of the stems (being first sorted as to colour and thickness) are formed into a plait of generally thirteen straws, which is afterwards knitted together at the edges into a circular shape called a 'flat' or 'hat.' The fineness of the flats is determined by the number of rows of plait which compose them (counting from the bottom of the crown to the edge of the brim); and their relative fineness ranges from about No. 20 to No. 60, being the number of rows contained in the breadth of the brim, which is generally eight inches. They are afterwards assorted into first, second, and third qualities, which are determined by the colour and texture, the most faultless being denominated the first, and the most defective the third. These qualities are much influenced by the season of the year in which the straw is plaited; spring being the most favourable, both for plaiting and bleaching. The dust and perspiration in summer, and the benumbed fingers of the workwomen in winter, when they are compelled to keep within their smoky huts, plaiting the cold and wet straw, are equally injurious to the colour of the hats, which no bleaching can remedy. The flats are afterwards made up in cases of ten or twenty dozens, assorted in progressive numbers or qualities. The *Brozzi*-make bears the highest repute, and the *Signa* is considered secondary; which names are given to the flats from the districts where they are plaited. Florence is the principal market; and the demand is chiefly from England, France, Germany, and America.

Some years ago M. Chateauvieux, in a collection of letters addressed to M. Pictet, gave the following account of what came under his notice while travelling through Tuscany. He says, "The road I travelled was bordered on both sides by village-houses, whose distance from each other did not exceed one hundred paces. They are all built of brick; and the architect has bestowed upon them a justness of proportion and an elegance of form unknown in our climates. They consist of a single pavilion, that has often but one door and two windows in front. These houses are always situated along the road, and separated from it by a terrace and supporting wall, some feet in breadth. Upon this wall usually stand several vases of the antique shape, containing aloe plants, flowers, and young orange-trees. The house itself is entirely covered by vine-branches; so that, during summer, one knows not whether they are so many pavilions of verdure, or dwellings prepared for winter. In front of these houses, swarms of young country-girls are seen, dressed in white linen, with corsets of silk, and straw hats adorned with feathers inclining to one side of the head. They are constantly occupied in braiding the fine plait, the treasure of this valley, from which the straw hats of Florence are made."

After this somewhat highly coloured description, Chateauvieux proceeds to state that the straw hat manufacture has been the chief source of wealth along the valley of the Arno, and that the mode of conducting it is as follows. Each young girl buys for a few pence the straw she wants; and then, after exerting her skill in braiding or plaiting it, sells for her own profit the hats she has prepared. The money she thus earns constitutes her portion. The father of the family has, nevertheless, the right to require of the women belonging to his house a certain amount of rustic labour on the farm; but this labour is performed by deputy, for the straw-workers, out of the produce of their labour, pay females from the mountain-districts to do the field-work instead of them: a curious exemplification of the mode in which industry becomes subdivided when allowed to follow its natural course. One of the straw-workers (at the time Chateauvieux wrote) could earn from thirty to forty sous a-day in plaiting straw; while she could hire a poor Apennine woman to do her field labour for eight or ten. By this commutation of service, the straw-workers preserved the delicacy and flexibility of finger which was necessary for their fine and nice work, and which would be spoiled by such work as would harden and stiffen the hands.

## CHAPTER IX.

### LEATHER :—TANNING, TAWING, DRESSING, CURRYING.

The processes involved in the fabrication of leather, although in many respects remarkable and interesting, are very little understood beyond the circle of manufacturers and dealers. It is generally known that the avocations of the tanner, the currier, the fellmonger, the tawer, the leather-dresser, all relate in some way or other to the preparation of leather; but the relation which these employments bear one to another is not so well understood. The matter will be better appreciated by bearing in mind the object of the various processes whereby skin is converted into leather. The gelatinous portion of the skin is made to combine with chemical substances artificially applied, and by this combination the new substance, leather, is produced. The ingredients employed for the conversion of skin into leather are different in different cases, and give rise to various subdivisions of employment in the leather-manufacture. The classification of the different kinds of leather may be conveniently made according to the modes of manufacturing them; whether by *oak-bark*; by *sumach*; by *alum*; or by *oil:* these four varieties being remarkably distinguished one from another.

The leather prepared by *tanning with oak-bark* is the hide of the ox, the calf, and the horse, all of which possess sufficient firmness to be applied to the manufacture of shoes, harness, and other articles requiring great strength and durability. The skins prepared by a substance called *sumach* are principally those of the goat and the sheep; and the leather resulting from the process is *morocco leather*, for coach-linings, chair-covers, book-binding, ladies' shoes, &c.; *roan* for shoes, slippers, and common book-binding; and *skiver*, an inferior leather, for hat-linings, pocket-books, work-boxes, toys, and other cheap purposes. The skins dressed in *alum* are principally those of the kid, the sheep, the lamb, and in some instances the calf; and the leather produced is principally employed for gloves and ladies' shoes. Lastly, the skins dressed in *oil* are those of the sheep, the buck, and the doe, and the resulting leather is that of which riding-gloves and similar articles are made, as well as the soft wash-leather, or shamoy leather, familiar to every one.

Although the processes whereby these varieties of leather are produced differ very distinctly one from another, yet the establishments wherein they are conducted present a generally similar appearance. The tan-yards and leather-manufactories of Bermondsey each present to the view of a stranger an open court or yard surrounded or partially surrounded by buildings, some of which are so constructed as to admit the access of air to every part of the interior. The surface of the court or yard is in most cases intersected by pits, or square cisterns, in which the skins are steeped during some part of the manufacturing process.

1. *Leather prepared by Tanning.*—When an ox has been slaughtered, the hide removed, and the flesh trans-

ferred to the butcher, the hide is sold to the tanner, by him to be converted into the thicker kinds of leather. The hide passes into his hands with the horns attached; and he separates these from the hide, and sells them to the comb-makers and other manufacturers of horn. The hair is also attached to the hide, but the removal of this is a more difficult operation.

When the hide is purchased by the tanner, there are little bits of flesh, &c., adhering to the inner surface; and these are removed by a process called 'fleshing.' The hide is spread out over a convex wooden bench or 'beam,' and is then scraped with knives of a peculiar shape, by which all extraneous matters are removed, and the hide is pared down to the cutis. After this process the hair is to be removed, and this is effected in one of two ways, according to the nature of the skin. One method consists in mixing together quick-lime and water, and immersing the hide in the solution; after remaining there several days, and having the lime-water renewed occasionally, the bulbous roots of the hair have become so far loosened by the action of the lime, as to be easily pulled out. The hide is then spread out on the beam, and 'unhaired,' that is, scraped with a knife till the hair is removed. In the other method, adopted in some kinds of skins which would be injured by the action of lime, several skins or hides are placed in a close chamber, where they undergo a kind of natural fermentation, sufficient to loosen the hair from the skin.

When by either of these methods the hair has been removed, the hide is 'grained,' or scraped, and then subjected to a process whereby the pores are opened and prepared for the reception of the *tan* afterwards to be applied. In some cases this consists in steeping the hide for some days in a sour solution of rye or barley flour; in others, the bath is a very weak solution of sulphuric acid in water. The hide becomes swollen, softened, and the pores ready prepared for the reception of the tan.

The bark, the roots, and occasionally the leaves of a considerable number of plants yield, by soaking in water, an astringent solution, usually of a yellowish brown colour. This solution has a peculiar action on the living skin, corrugating and constringing it; and when applied to dead skin, has the property of converting it into leather. These vegetable substances contain a principle called *tannin*, which is the agent concerned in converting skin into leather. Provided the tannin is obtained, it matters not much to the success of the process what substance yields it; and the tanner, therefore, employs that which is, on the whole, the most effective and the most economical.

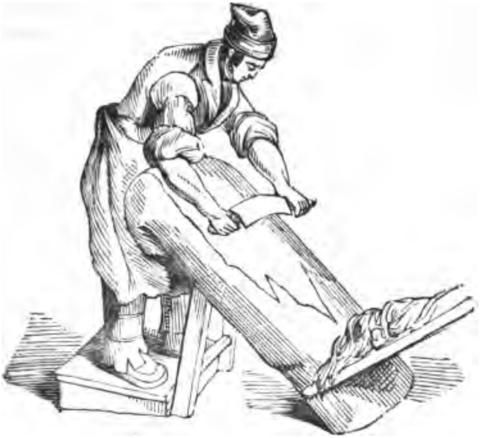
To detail the various systems adopted by different tanners would be wholly foreign to our purpose. The process is so slow a one, and the desirability of increased speed so great, that patent after patent is taken out on the subject; and almost every tanner has some process peculiar to his own establishment. When the hide is properly cleaned and brought to the state called 'pelt,' it is ready to be placed in one of the tan-pits. These pits are generally rectangular cisterns, whose upper edge is level with the ground, and whose interior is lined with wood. The tanning ingredient, generally oak-bark, is steeped in the cistern of water, and the solution is then technically termed 'ooze.' The hide is in the first instance put into a pit containing nearly-spent ooze, in which hides have already been steeped, and which has consequently lost more or less of its tanning principle. In this pit the hide is frequently stirred and turned to ensure the equable action of the tan on every part. The hide is then transferred to a pit containing stronger ooze, or else is stratified with crushed bark; several hides being laid one on another, and steeped in water. Whether the hides be placed at once in prepared solution of bark, or be stratified with bark in a pit containing water, depends upon the system of tanning pursued by the manufacturer, and upon the quality of the hide; but in either case the hides are exposed to renewed portions of the tanning ingredient from time to time, until the tannin has combined intimately with the animal substance. In most tanneries several months are consumed in this process of steeping in the tan-pits; and although numerous patents have been granted for improved and more expeditious processes, the limited extent to which these are adopted seems to show that there is some advantage afforded by lengthened time, not altogether attained by the speedier processes. This is a point on which we cannot enlarge here: it must suffice to say that the object of tanning, whether by a slow or a speedy process, is to cause the tanning principle to penetrate into all the pores of the hide from surface to surface: when this is effected, the hide has become transformed into leather. When the hide is tanned, it is hung up in an airy loft, or drying-room; and during the process of drying is compressed by beating, by pressure with a steel instrument, or by being passed between rollers, which gives it a smooth and dense texture.

The stoutest hides, from bulls, buffaloes, oxen, and cows, are tanned in a way more or less resembling that above detailed, and are then used principally for the soles of boots and shoes. The time employed in tanning a hide for the soles of men's boots in general is from six to twelve months; while a still thicker quality, known as 'butts' or 'backs,' frequently consumes fifteen or eighteen months in the process. The skins of calves, seals, and the lighter kinds of horse and cow skins, are tanned to form the 'upper leathers' of boots and shoes, and are prepared in a somewhat similar, but more expeditious manner. After having been 'unhaired,' they are steeped for eight or ten days in an alkaline liquor, being at intervals taken out and scraped on both surfaces, by which the lime, oil, and gelatinous matter are forced out from between the pores, and the skin rendered soft, pliant, and fit to receive the tanning ingredient. They are then exposed to the action of tan in the tan-pits until converted into leather.

Leather intended for the upper parts of boots and shoes, for saddlers, and for coach-makers, passes into the hands of the currier after tanning, for the purpose of being softened, equalized in thickness, smoothed, blacked, &c. The currier dips the tanned skin in water to moisten it, and then softens the texture by beating it with a 'mace:' this instrument consists of a wooden handle two or three feet long, with a cubical head at one end. He then places the skin on an inclined plane called a 'horse,' and equalizes the thickness by the aid of a broad, straight, two-handled knife, called a 'cleaner,' which is worked in such a manner as to shave off the superfluous thicknesses of the skin, After this the leather is thrown again into water, and rubbed on the grain or outer side with pumice or gritto the manufacturers of glue and size; as are likewise the fleshings and other scraps from the thicker hides and skins prepared by the tanner.

A solution of lime in water being prepared, the goat-skins, after being fleshed, are allowed to soak therein for four or five weeks. During this time they are frequently 'drawn,' a process represented in the preceding cut, and consisting in taking the skins out of the pit, laying them in a heap on the side, allowing them to lie thus for a certain time, and immersing them again: all this has the effect of causing the lime to act equally on every part of the hairy covering, and the lime-water is renewed once or twice, to aid in producing the desired effect.

When the liming has been carried to such an extent that the hair can be easily pulled out with the finger, the goat-skins are drawn from the pits, and conveyed in wheel-barrows to the 'fleshing-shop.' In this shop are a number of 'beams,' as they are called, consisting of convex work-benches or stools sloping downwards from one end to the other, and supported on a frame or stand. Each goat-skin is laid smoothly on a 'beam,' with the hairy side uppermost; and the workman, standing at the upper end of the beam, scrapes off all the hair by means of a double-handled knife. The convex form of the surface on which the skin is laid, and the peculiar form given to the knife, enable the workman to take off all the hair very completely. The operations of 'fleshing,' of 'unhairing,' and of 'graining,' are so nearly alike in their general appearance, that the following cut will sufficiently show the character of the whole; the principal difference being in the edge of the knife employed by the workman.



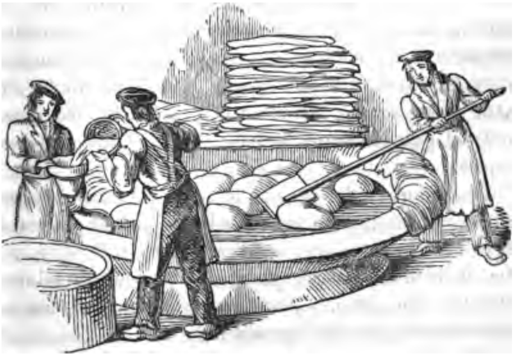
Unhairing a Goat-skin.

The hair which is thus removed from the goat-skins is, after being cleansed, sold to the carpet-manufacturers and to plasterers.

After the process of 'unhairing,' the goat-skins are again soaked in lime-water for two or three days, and are then again 'fleshed,' or scraped on the inner surface, by which the cutis is brought to a tolerably clean state. But the long steeping which the skin has undergone has had the effect of driving the lime into the pores, insomuch that the tanning principle contained in the sumach, afterwards to be applied, would not be able to reach the heart of the skin. The tanning, therefore, cannot be commenced until the lime is removed and the pores opened. A solution called the 'pure' or the 'pewer' is prepared in a large vessel, and into this the skins are immersed: there is an alkaline quality in the solution employed, which has the effect of removing the lime from the pores, and the manufacturers seem to have failed hitherto in finding more than one substance which yields this quality effectually. Whether chemistry may hereafter afford them a more extensive range it is not for us to say, but such would seem to be at least probable. After being 'pured' for some time, the skins are taken out and scraped well on both sides, for the sake of removing as much of the lime and the albumen as may be removable by these means; and after this they are steeped again.

By these operations the pores of the goat-skin are so far opened and cleared as to prepare them for the reception of the tanning principle. The substance employed in tanning stout hides is, as we before explained, oak-bark; but for goat-skins the tanning ingredient is a vegetable substance called *sumach*. This is the powder of the leaves, peduncles, and young branches of a plant called the *Rhus coriaria*, growing in Sicily, Italy, and Hungary. It is one of the substances experimented on by Sir H. Davy in his inquiry into the tanning properties of various bodies; and he found it to contain a large proportion of tannin. It contains also a light colouring-matter, which seems to render it useful for the tanning of light-coloured leathers. It is employed extensively in dyeing, as well as in leather-dressing.

The manner in which this tanning ingredient is forced into the pores of the goat-skin is exceedingly curious. The sumach is mixed with water; but if the skins were immersed indiscriminately in the solution, or even laid smoothly one on another, the sumach would not act equally on the whole surface. To produce the desired equality of action, the following singular plan is adopted: —The wet goat-skins are taken from the 'pure,' or alkaline solution, and sewn up by women into bags, each skin forming a bag with the grain side outwards, and having no opening except a small one at that part which had formed the hind shank of the animal. These bags, as soon as made, are thrown into a vessel of water, and examined, to see that they are well sewn up, and free from holes. They are then taken to the sumach-tub, where the process represented in the annexed cut is carried on. A large shallow circular tub, twelve or fifteen feet in diameter, is filled with hot water containing a little sumach, and near it is a small vessel containing a strong solution of sumach in water. Two men and a boy, standing on one side of the tub, then fill the bags



Sumach Tan-tub.

with the sumach-solution thus: the boy takes a bag, and inserts into its mouth the stem of a funnel, the mouth of which is uppermost. One of the men then nearly fills the bag, through the funnel, with the solution, which he ladles from the smaller tub. The other man takes the bag from the funnel, and by a peculiar action of the breath fills with wind the remaining portion of the interior, and ties up the mouth with string. The air has the effect of distending the bag until quite free from wrinkles, and also of causing it to float in water. All the bags, after being thus filled, are thrown into the large vessel, and are kept there about three hours, occasionally stirred and moved about with a wooden instrument. The effect of this arrangement is, that the solution of sumach contained within each bag is enabled to exert its full action on the skin in an equable manner, and to penetrate entirely through the substance. The thickness of these goat-skins is so very much less than that of the hides formerly described as being tanned by oak-bark, that the tanning principle of the sumach, aided by a certain temperature in the skin and the solution, is enabled to produce its effect in a few hours. The sumach-tubs present a singular appearance when three or four dozen inflated goat-skins are floating about in the contained liquor.

Once during the process of sumaching the skins are removed from the tub and placed on a rack or perforated bench at the side; they are heaped one on another, and by their own weight press all the sumach solution through the pores. Another sumaching and another pressing complete the operation.

The bags are next removed to another building, where the seams are loosened, the bags opened, and the sediment remaining from the sumach removed from the inside: this sediment, which often consists principally of yellow sand nefariously mixed with the sumach before it leaves Sicily, is of no further use in leather-dressing, and is taken away to be used as manure. The goat-skins, after being thoroughly washed, are laid out smooth on a sloping board, and 'struck,' that is, scraped and rubbed out as smooth as possible. In this smooth state the skins are hung up in a loft, and when thoroughly dried they are said to be 'in the crust.'

The skins are then nearly ready for the process of dyeing. It is generally known that most morocco leathers present beautiful and vivid colours, and to produce these the skins have to undergo a very careful process of dyeing. The drying in the loft has had the effect of shrivelling the skins in some degree; to obviate which, and to prepare them for the reception of the dye, the skins are wetted, and 'struck out,' or smoothed again. The dye-house usually presents those general features which, whether the substance to be dyed be cloth or leather, are observable in such places; such as coppers for the reception of hot-water or logwood solution, square tanks for containing the dye, frames whereon to suspend the skins in various solutions, and other similar arrangements. As many of the ingredients used in dyeing are costly, and as the finished leather is intended to be seen only on one surface, it is customary to lay two skins in close contact before dyeing, so that the dye-liquor may not be wasted by acting on both surfaces of each. The dyeing ingredients employed, the number of immersions which the skins undergo, the changes in the solutions to which the skins are exposed, and the time employed in the various parts of the process, are points involving much practical skill, and on which we can say but little. The crimson, the scarlet, the purple, the indigo morocco-leather, all require particular modes of treatment, arising from the qualities of the dyeing ingredients used.

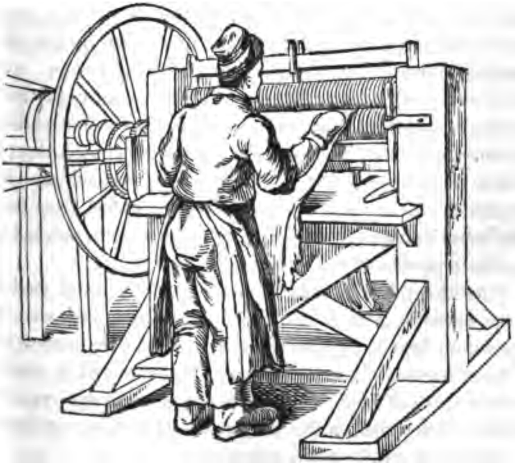
After the dyeing, the skins undergo two or three processes of rubbing, which seem to act somewhat on the principle of currying, by giving a softness and pliability to the leather. This is especially the case in the finishing process, by which the wrinkled appearance is given to the material. Every one knows that the coloured surface of morocco leather has the appearance of having been indented all over by an instrument sharp enough to leave permanent depressions, but not so sharp as to cut the leather. This effect is produced on the smooth goat-skin thus:—The workman lays the skin on a sloping bench, with the dyed surface uppermost, and rubs it forcibly with a ball made of some hard wood, such as box. The ball is about the size of a small lemon, and has on its surface a number of fine parallel grooves. As the ball is worked over the leather in the direction of these grooves, it leaves permanent marks thereon, and thus gives rise to the appearance which distinguishes morocco from all other kinds of leather. Nothing can exceed the beauty and flexibility of the morocco leather made from the finest goat-skins: the finishing of the grooved ball makes it very pliable, while the nature of the skin itself gives it great durability and toughness.

We have before stated that there is an inferior kind of morocco leather, made of sheep-skin. This, under the name of 'imitation' morocco, is largely used for inferior or economical purposes; and though it is inferior to the other kind in suppleness and durability, its superficial appearance is very nearly equal: indeed it is to this latter fact, combined with greater cheapness, that we may attribute its extensive manufacture. In the manufacture of morocco leather from sheep-skins there are not many points of difference from the analogous manufacture from goat-skins; but it will be necessary to speak briefly of the different states in which the skins come into the hands of the leather-dresser.

There are in Bermondsey several manufacturers called *fellmongers*, whose business it is to bring sheep-skins into a certain state of preparation before the leather-dresser commences his operations thereon. The skins from nearly all the sheep slaughtered in London are conveyed to a skin-market in the western part of Bermondsey, and there sold by factors or salesmen, who act for the butchers, to the fellmongers. The skins are bought and sold with the wool on, and the labours of the fellmonger relate to the separation of the one from the other, and the disposal of the wool to the woolstaplers, most of whom live also in Bermondsey, and the 'pelts' or stripped skins to the leather-dressers and the parchment-makers. The trade of a fellmonger is more dirty and disagreeable than even that of a leather-dresser, on account of the mode necessary to be adopted for the separation of the wool from the pelt. These remarks, so far as the leather-dresser is concerned, apply only to sheep-skins; for the skins of the goat, the kid, the buck, the doe, and one or two other kinds of animals which have a hairy rather than a woolly covering, come into his hands before the hair has been removed, and the process of 'unhairing' is then effected.

In the manufacture of sheep-skins into 'imitation' morocco, and into roan leather, a routine of operations occurs not very different from that sketched above. Both kinds are prepared by sumach-tanning; and the preparatory and subsequent processes are for the most part similar to those necessary for goat-skin morocco. There are, however, one or two points of difference which must be noticed. The skin of the sheep, from the organization which promotes the rapid growth of wool, contains a much larger amount of grease, or oleaginous matter, than the skin of the goat; and it is essential that this be removed before the tanning principle is brought to act upon the skin. To effect this, the skins, shortly before being placed in the sumach-tan, are subjected to the action of a hydrostatic press, which by a pressure of many tons forces out the extraneous matters from the pores of the skin. The kind of leather called 'roan' does not present the wrinkled or grained appearance of morocco leather, a difference which results from the different mode of finishing after the dyeing, the grooved balls not being used for the roan leathers.

The kind of sheep-skin leather called 'skiver,' used for common bookbinding, hat-linings, pocket-books, work-box covers, and other cheap purposes, deserves notice for a very remarkable process involved in its manufacture, viz., the 'splitting' of a skin into two thinner skins. Thin as a sheep-skin is, and supple when wetted, it might be thought that the operation of splitting or slicing it into halves, without cutting holes in either, would be an impossible task; yet this is effected with the utmost accuracy. The object aimed at in this operation is twofold, viz., to obtain a thin kind of leather for some purposes for which a sheep-skin in the natural state would be too thick, and to obtain a quality of leather which could be sold at a lower price than that made from whole skin. The principle of the machine is this:—Two rollers, ranged horizontally in a frame, are made to rotate in opposite directions, the vacancy between them being only just sufficient to admit a soft wetted sheep-skin or pelt. The rotation of the rollers causes the skin to be drawn slowly between them; but it cannot do so without encountering the blade of a very



Leather-Splitting Machine.]

sharp knife, which has a reciprocating horizontal motion, in such a position as to cut the skin into two thicknesses as it passes the knife, one-half passing over, and the other under the blade. A most ingenious contrivance is adopted for yielding to any inequalities which may occur in the skin. One of the rollers is made in several pieces, so adjusted that in passing over any thickened portions of the skin the common aperture between the rollers is widened at that part. It is one of the consequences of the construction of the machine, that one of the semi-thicknesses or sections must be equable and level in every part, while any inequalities which might have existed in the original skin will be thrown into the other section. Either section, the 'grain' side or the 'flesh' side, may have this equable thickness given to it, according to the mode in which the skin is adjusted on the rollers; and the two portions may have various ratios given to their thicknesses, according to the position of the vibrating knife opposite the opening between the rollers. A sheep-skin of the usual size occupies about two minutes in splitting, during which time the knife makes from two to three thousand vibratory motions to and fro, cutting a minute portion of the skin at each movement.

As the thin 'skivers' are more readily acted on by the sumach-tan than the thicker goat-skins, they are not sewn up into bags like the latter, but are immersed in the sumach-tub in an open state, and are tanned in a very short space of time. The subsequent operations require less delicacy than in the preparation of morocco leather, and do not call for much remark.

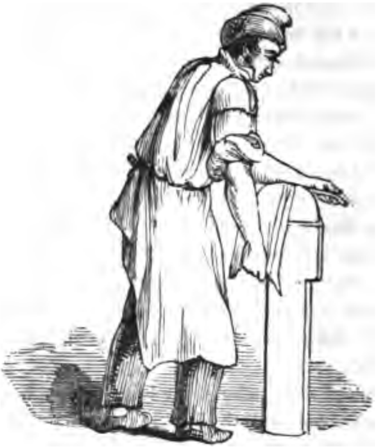
Among the varieties of leather tanned with sumach is the 'enamelled leather,' now occasionally employed for ladies' shoes. This is made of seal-skin or thin calf-skin, coated, after tanning, with a peculiar kind of varnish or japan capable of yielding a brilliant gloss.

3. *Leather prepared with Alum.*—The technical name of 'tawing' is frequently applied to the general routine of operations whereby alumed leather is produced. This variety of leather is in many cases left white or undyed, and has a peculiar softness when finished. The skins which undergo the process of 'tawing' are those of the kid, the sheep, and the lamb; the first-named of which yield the well-known 'kid leather' of which gloves and ladies' shoes are made; while the white leather made from sheep-skin is used for lining shoes and other inferior purposes. The cheap kid gloves which are displayed in the shop-window of the hosier are generally made from lamb-skin, and may be considered as an imitation kid.

The kid-skins which form the staple of this branch of the manufacture are brought from Italy: they are very small in size, and have the hair on. The first operation to which they are subjected is steeping for the space of three days, by which they become soaked and softened; they are then 'broken' on the flesh side, a process resembling that to which goat-skins are subjected: the skin is laid on a beam or convex bench, with the flesh side uppermost, and is then scraped: this seems to facilitate the action of the lime in the next process. After the 'breaking,' the kid-skin is immersed in lime-water in a pit for about fourteen or sixteen days, by which the hair becomes in some measure loosened from the pelt; and at the end of this period the operation of 'unhairing' is effected in the same manner as for goat-skins. In a few days after this process the skin is 'fleshed,' to procure a clean surface on the inner side, and after this the pores are opened and the lime 'killed' (to use a technical term). This opening of the pores is effected not by the alkaline solution called the 'pure,' as in goat-skin dressing, but by steeping the skin in a solution or 'drench' of bran and water. When this is effected, the skin is laid down on the 'beam' with the grain side uppermost, and 'struck,' or forcibly worked with a knife, whereby the impurities are worked out from within the pores. After a further steeping for a day or two in bran and water, the skin is in a state to undergo that process which constitutes the principal difference between sumached leather and alumed leather. Instead of being sewn up into bags filled with sumach liquor, and immersed in a tub of hot water, the skins are put into a kind of barrel called a 'roundabout:' this barrel has a door or opening in one part of its curved surface, through which the skins are placed; and when the water and ingredients are added, the door is closed, and the barrel made to rotate rapidly. The effect of the rotation is to cause the impregnated liquor to act intimately on every part of the skin. The substances placed in the barrel to act on this skin are, for the commoner kinds of leather, alum and salt; and for the better kinds, alum, salt, flour, and yolk of eggs: these latter ingredients are for the most part absorbed into the substance of the finer kid leathers, and seem to have the effect of imparting that beautiful softness and plumpness which such leather presents. About twelve pounds of alum, and a little more of common salt, are sufficient for about two hundred skins. Sometimes the skins are not put into the 'roundabout,' but are merely steeped in the solution in an open tub: whether the one or the other plan be adopted, however, a period of five minutes is sufficient to produce the effect. In that part of the 'tawing' process wherein eggs are employed, the eggs are broken, in the proportion of one to each skin, and the yolks only are mixed with water and a little meal in a tub: the skins are then introduced, and are trampled by the naked feet of a man until the egg has been thoroughly imbibed. The eggs employed for this process are imported from France: for some of the factories sixty or seventy thousand are purchased every spring, and are preserved in lime-water till wanted, a mode by which they may be kept perfectly sweet for two years.

The tawed skins, after being hung up in a loft to dry, are stretched out, smoothed, and softened, by the process of 'staking.' There is used for that purpose a wooden block, having at the upper end a steel instrument, shaped somewhat like a cheese-cutter, but not having a very sharp edge. Over the semicircular edge of this instrument each skin is drawn very forcibly, the workman holding it in both hands, and scraping the surface in various directions on the steel edge. This has the effect of stretching out the skin to its full extent, and of removing all the rigidity and stiffness which it had acquired in the previous processes. This is, indeed, one of the many processes of violent rubbing, scraping, or friction to which every kind of leather is more or less subject in the progress of manufacture; but in this instance the rubbing is effected when the leather is nearly in a dry state.

For the production of 'imitation' kid leathers the skin



'Staking' tawed Leather.

of lambs is employed; and for this purpose lamb-skins are imported from the shores of the Mediterranean. They are imported with the wool yet on them; and as this wool is valuable, the leather-manufacturer carefully removes this before the operations on the pelt commence. The wool is of a quality which would be greatly injured by the contact of lime; and therefore a kind of natural fermentation is brought about as a means of loosening the wool from the pelt. There are close rooms or vaults, into which the lamb-skins are introduced, in a wet state, after having been steeped in water, 'broken' on the flesh side, and drained. The temperature of these rooms is nearly the same all the year round, a result obtained by having them excluded as much as possible from the variations of external temperature; and the result is that the skins undergo a kind of putrefactive or fermenting process, by which the wool becomes loosened from the pelt. During this chemical change, ammonia is evolved in great abundance: the odour is strong and disagreeable; a lighted candle, if introduced, would be instantly extinguished, and injurious effects would be experienced by a person remaining long in one of the rooms. It is a point of much nicety to determine when the fermentation has proceeded to such an extent as to loosen the wool from the pelt; for if it be allowed to proceed beyond that stage, the pelt itself would become injured.

When the fermentation is completed, generally in about five days, the skins are removed to a beam and there 'slimed,' that is, scraped on the flesh side to remove a slimy substance which exudes from the pores. The wool is then taken off, cleaned, and sold to the hatters for making the bodies of common hats. The stripped pelts are steeped in lime-water for about a week, to 'kill' the grease, and are next 'fleshed' on the beam. After being placed in a 'drench,' or solution of sour bran, for some days, to remove the lime and open the pores, the skins are alumed and subjected to nearly the same processes as the true kid-skins. These Mediterranean lamb-skins do not in general measure more than about twenty inches by twelve; and each one furnishes leather for two pairs of small gloves. These kinds of leather generally leave the leather-dresser in a white state; but undergo a process of dyeing, softening, 'striking,' &c., before being cut up into gloves.

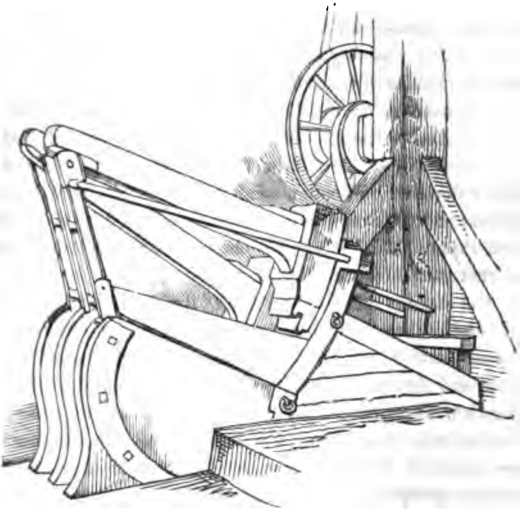
There are a few other kinds of skins prepared by aluming, but the general routine of processes is pretty much the same as herein described.

4. *Leather prepared with Oil.*—The 'killing' of the animal quality of skins (if we may use such an expression), whereby the skins are converted into leather, seems to consist in forcing out from the pores some albuminous substance, and replacing it with a substance of another kind. Thus in tanning hides, the tannin penetrates into the substance of the skin and combines therewith; in sumaching, the larger portion of the sumach does the same thing; so do the alum, salt, egg, and meal in tawed leather; and lastly, so does the oil in the kind of leather now to be noticed.

That variety of leather called chamois, chammy, shammy, shammoy, shamoy, or shamoyed, which is the characteristic of oil-leathers generally, was originally a beautifully soft leather prepared from the skin of the chamois goat. A similar mode of manufacture is now adopted for sheep and other skins, but the name of chamois, modified in the spelling to a strange degree, is still applied to the leather produced. Mr. Aikin, in one of his lectures before the Society of Arts, made the following statement in reference to shamoyed leather:—"Till a few years ago, there was an immense quantity of the skins of sheep, goats, and deer shamoyed in England. Breeches of this article, either white or dyed, were commonly worn by persons whose occupations or amusements led them to be much on horseback. They were worn by most of the cavalry of Europe; and the English shamoyed leather, being of extraordinary good quality, was employed in clothing not only our troops, but the cavalry of Prussia, Austria, and most of the other German states. In the campaigns in Spain during the last war, it was discovered by the British commander that the health of the horse-soldiers was seriously affected in wet weather by the leather that they wore, which, fitting close to the skin and being long in drying, chilled the men and rendered them liable to rheumatism and other diseases. Woollen cloth was accordingly substituted; and the example having been followed by Austria and Prussia, this change has occasioned a great decline in that branch of the English leather-trade."

The shamoy leather, whether of the superior kind just alluded to, or of that more humble description known as 'wash-leather,' is prepared nearly as follows:—The deer and sheep skins undergo the earlier stages of preparation nearly in the same manner as for other kinds of leather, such as washing, liming, beaming, &c. It must be remarked, however, that the inferior or thinner kinds are generally made of split skins, the more irregular of the two halves, generally the flesh side, being used for this purpose; the other half being alumed or tawed for 'skiver' leather. In general, oil-leathers have the 'grain' surface of the skin entirely removed before any oil is applied; as this removal not only affords a much softer surface, but greatly increases the extensibility of the leather, which still remains sufficiently strong and elastic for the purposes to which it is applied. This 'frizing,' or removal of the grain, is effected either by the edge of a round knife or a rubber of pumice-stone.

The lime and other obstructions to the porosity of the skin having been removed by steeping in sour bran and water the skins are wrung or pressed as dry as possible,



Oil-Leather Fulling-Stocks.

and are then ready for the reception of the oil. This is forced into the pores by means of 'fulling-stocks,' consisting of two stocks, which may be likened to heavy wooden hammers; the head, covered with copper, being attached to a long beam or handle lying in an inclined position. Near the lower end of each a wheel revolves, by which each hammer is in turn lifted up and let fall again, through a space of about a foot. This they do in a kind of trough, so that any substances which may be placed in the bottom of the trough receive a blow from each stock every time it descends. The upper or handle end of each stock is so adjusted as to work on a pivot or axis.

Into the trough connected with these fulling-stocks the leather is placed; the stocks are set in action; and the leather is beaten alternately by one and the other until rendered as dry as possible. Cod-oil is then poured on the skins in the fulling-machine, and this is forcibly driven into the pores of the skins by another lengthened beating with the stocks. The trough is so formed in an arc or curve, that as the stocks beat the skins, the latter become turned gradually over and over, whereby every part of each is exposed to the operation. When the oil is beaten in, the skins are removed, shaken out flat, hung out in the air to dry, again put into the fulling-mill, supplied with fresh oil, and subjected to a renewed fulling with the stocks. Again and again is this repeated; oil being poured on the skins in small quantity, and then beaten into the pores by means of the stocks. This occurs as many as eight or nine times, oil being added each time, and well beaten in, until two or three gallons of oil have been imbibed by one hundred skins.

When the oil is thus forced into the heart of the skins, they are placed in large tubs, where they undergo a kind of fermenting process, by which a more intimate action of the oil upon the fibres seems to be induced. These tubs are placed in one of the lower buildings near the fulling-stocks; and from them the skins, now converted into shamoy leather, are removed, to be immersed in a weak solution of potash. This latter process is intended to remove whatever excess of oil may have remained in the leather. After being hung up to dry in the open air, the leather is finished.

The various forms of leather, thus finished, are then placed in the hands of those artisans by whom they are to be worked up into useful articles. Of these, boots and shoes are decidedly the most important. The manufacture of such articles, however, is too familiar in its general features to need much consideration.

Another mode of employing leather is for the making of gloves; and as these articles form a kind of link between the textile manufactures on the one hand and the leather manufacture on the other, it may not be inappropriate to close this volume with a few details concerning gloves and glove-making.

## CHAPTER X.

### GLOVES AND GLOVE-MAKING.

The manufacture of gloves is one of those few which are so far removed from the class of factory operations as to afford employment to country-people and cottagers at their own homes, and from the nature of the work it is likely so to continue. Where no advantage is to be gained by a combination of different branches of labour, all tending to one end, beneath one roof, the less the freedom and independence of the labourer are interfered with, the better for all parties.

A slight examination of any of the usual kinds of gloves will show that whatever be the material of which they are formed, it is brought into shape by means of sewing with thread, silk, or worsted; but there may be some who have yet to learn that this is effected by the fingers, just as any other kind of needlework. Machinery has done much, but it has not yet made gloves; or, at least, such a feat, if achieved, is one of the curiosities of manufactures, and is not yet to be ranked among the features of the glove-trade. So far as the mass of glove-wearers are concerned, whether the gloves be "French" or "English," whether they be of silk, or cotton, or worsted, or leather—whether they may have cost four pence or four shillings, every seam of every glove has been sewn by the hand.

There are some very curious circumstances attending the glove, independent of its relation to manufacturing industry. It has in various countries and at different periods been the pledge of friendship, of love, and of safety; the symbol of hatred and defiance, of degradation and honour; the token of loyalty; the tenure by which estates have been and are held; and a customary offering on occasions both of sorrow and of joy. From an interesting little volume on this subject by Mr. Hall, we will extract a few examples illustrative of these customs and observances of the glove.

The first law relating to this subject is dated in the year 790, when Charlemagne granted a right of hunting to the abbot and monks of Sithin, for the purpose of procuring skins for making gloves and girdles. The abbots and monks having generally adopted the use of gloves about this period, the bishops interfered, claiming the exclusive privilege for themselves; and by the Council of Aix, in the reign of Louis le Débonnaire, about the year 820, the inferior clergy were ordered to refrain from deer-skin gloves, and to wear only those made of sheep-skin, as being of humbler quality. It has been deemed not improbable that at this period the monks made their own gloves, as they made many other articles for their own use.

So far as England is concerned, the first commercial notice of the glove-trade is dated about the year 1462, though gloves had been worn in England for centuries before. By a law or edict of this date, gloves were prohibited from being imported into this country by reason of the protection which it was deemed proper to give to this branch of home manufacture. Two years afterwards armorial bearings were granted to the glovers by Edward IV. At what prices gloves were valued in that reign does not appear; but in the "Privy Expenses of Henry VIII." appear the following two items :—

| | | |
|---|---|---|
| " Item. | Paied the same daye to Jacson for certeyne gloves fetched by the serjeant apoticary . . . . . | iiijs. xd. |
| " Item. | Paied Jacson for a douzin and halfe of Spanysshe gloves . . . . | vijs. vjd." |

In many of the customs relative to the glove, the *gauntlet* is often spoken of as being of equivalent meaning, but the two are sufficiently different. The gauntlet introduced into England by the Conqueror was a mailed glove, that is, a stout glove made of deer or sheep skin, having jointed plates of metal affixed to the back and fingers, allowing the perfect use of the hand; sometimes there was attached to the top of it a circular defensive plate, protecting the wrist and meeting the armour which covered the arm. The metal of which these plates were composed varied according to the rank or fancy of the wearer; some were of gold or silver inlaid, others of brass, and some of steel. The gauntlet or buff-glove of the days of the Commonwealth, such as we see in representations of the troopers of the seventeenth century, consisted of a sheep-skin glove, with a stout handsome buffalo-hide top coming half-way up the arm, contributing much to a military appearance, and serving as a protection to the arm. Such gauntlets are worn by several regiments of cavalry in our own day.

The ceremonial use of the glove in matters of investiture and tenure is illustrated in many ways. We may take, as an instance, the investment in the family of Dymocke of the manor of Scrivelsby, under the condition of the head of the family acting as 'champion' at the coronation of the English sovereign, in which the glove plays a conspicuous part in the ceremony. The sovereign being seated in Westminster Hall, after leaving the Abbey, the champion enters, caparisoned as an ancient knight, and the herald-at-arms proclaims the challenge; the champion then throws down his gauntlet or glove, which is allowed to remain on the ground for a short time, and is then taken up again and returned to the champion: this is repeated a second time, after which the sovereign drinks to the champion's health, and presents him the cup: lastly, the champion takes up his gauntlet and retires. Taken in reference to modern taste and opinion, all this may seem to be mere mummery; but as a thing of other days it had a significant and important meaning in it. In like manner the Duke of Norfolk held the manor of Worksop on condition of paying certain small fees, and of finding the king a right-hand glove at his coronation, with which glove the king holds the sceptre with the dove, his right arm being supported meanwhile by the duke.

The glove has been deemed an emblem of firm possession. Thus the former kings of France used at their coronation to receive from the archbishop a pair of gloves, previously blessed, as an emblem of secure possession. A register of the parliament of Paris, dated 1294, states that "the Earl of Flanders, by the delivery of a glove into the king's hands (Philip the Fair), gave him possession of the good towns of Flanders, viz., Bruges, Ghent, &c." Favyn states that "the custom of throwing the glove is derived from Eastern nations; who, in all sales or delivery of lands, &c., gave a glove by way of livery or investiture." Security, as emblemed by the glove, was curiously illustrated by a custom prevailing until the last few years at Portsmouth; where, during an annual fair called the 'Free-Mart,' a golden or gilt glove was hung outside the door of the gaol, in the High Street, as a pledge that the persons of all who attended the fair were secure from arrest for debt during its continuance, which was about a fortnight.

Both honour and degradation have been typified by the glove, according to the circumstances attending the particular occurrence. Walsingham says that "George Clifford, Earl of Cumberland, was honoured by a glove being presented to him by Queen Elizabeth. The Queen had dropped it; when the Earl taking it up to return it to her, the Queen presented it to him as a mark of her high esteem. The Earl adorned it with jewels, and wore it in his cap on days of tournament." On the other hand, the same writer tells us, that when the Earl of Carlisle, in the reign of Edward II., was impeached, and condemned to die as a traitor, among other circumstances attending his degradation were, that his spurs were cut off with a hatchet, and his *gloves were taken off*.

Challenge and defiance have been, in various ages and countries, conveyed by the glove. Besides the instance given in reference to the 'Champion' of England, we have abundant evidence of such challenges. Shakspere, in 'Henry V.,' gives a scene which well represents the nature of the custom, wherein the glove may be deemed either a pledge or a challenge, or part of both :—

"*K. Henry*. Give me any gage of thine, and I will wear it in my bonnet. Then, if ever thou darest acknowledge it thine, I will make it my quarrel.

*Williams*. Here 's my glove: give me another of thine.

*K. Henry*. There.

*Williams*. This will I also wear in my cap: if ever thou come to me after to-morrow, and say 'This is my glove,' by this hand I will take thee a box on the ear.

*K. Henry*. If ever I live to see thee, I will challenge thee."

Sir Walter Scott's description of the interview between Rebecca and Beaumanoir, in 'Ivanhoe,' gives an instance illustrative of a very usual kind of challenge by champion-depute; while the scene with Bonthron in the church, in the 'Fair Maid of Perth,' similarly illustrates a formal act of defiance:—the glove in both cases being the emblem. In the 'Life of the Rev. Bernard Gilpin,' it is said, in reference to the northern borderers of the sixteenth century:—"He observed a glove hanging up high in the church in which he was preaching; which was placed there in consequence of a deadly feud prevailing in the district; and which the owner had hung up in defiance, daring any one to mortal combat who took it down." In the ancient 'Trial by Battle,' the plaintiff was wont to throw down his glove in court, which was then taken up by the defendant, as a token that they would settle their differences by the sword's point. A defiance by glove was made in the Court of King's Bench so late as 1818, and it was not till after that period that the law by which it was permitted was expunged from the statute-book.

How swearing 'by the glove' could have arisen is not very clearly to be seen, unless the glove be here, as in other cases, deemed an emblem of honour and probity. The reader will call to mind many scattered illustrations, somewhat similar to the following from the 'Merry Wives of Windsor:'—

> "*Falstaff.* Pistol, did you pick Master Slender's purse?
> *Slender.* Ay, *by these gloves*, did he—*by these gloves.*
> *Pistol.* Word of denial—froth and scum—thou liest!
> *Slender.* *By these gloves*, 't was he."

The presentation of gloves at weddings and at funerals is another curious item in the catalogue. A passage in the 'Winter's Tale' shows that the gift of gloves at weddings was common in Shakspere's time; and the same custom is alluded to in Ben Jonson's 'Silent Woman,' where Lady Haughty says to Morose:—

> "We see no ensigns of a wedding here,
> No character of a bridale:
> Where be our scarves and gloves?"

As to funerals, the practice of giving gloves at those solemnities has been traced back to early times. Pope Leo I. granted permission to bishops and abbots to wear gloves at funerals, and on certain other solemn occasions. Royal and other noble personages were often buried with gloves on; for on opening the tombs of kings and abbots, gloves have frequently been found either on the hands or loose in the coffins; and it was stated, as an unusual circumstance, that when the tomb of King Edward I. was opened, *no gloves* were found on his hands. In Philip I.'s monument, he is represented in a recumbent position, holding a glove in his hand; and many other cases are recorded, in which gloves are either buried with a royal or military personage, or hung up in effigy over his tomb.

The presentation of gloves as a gift, with or without money inserted in them, is another custom which has passed through many gradations of society. James I., when at Woodstock, received a pair of gloves as a gift from the University of Oxford. The same monarch used to receive New Year's Gifts from his subjects, generally consisting of elegant gloves; and so likewise did his predecessor, Elizabeth. There was formerly a custom of presenting judges with gloves; but this became an abuse, in a way which the following anecdote will illustrate:— A lady, a suitor in Chancery whose cause had been favourably decided by Sir T. More, presented him, on the next New Year's Day, with a pair of gloves containing a considerable sum of money. His remark was, "I accept the gloves: it would be against all good manners to refuse a lady's New Year's Gift, but the lining you will be pleased to bestow elsewhere."

Mr. Hall, in his 'History of the Glove Trade,' states that Scotland was the first country in which the glovers were incorporated. King Robert III. gave the glovers of Perth a charter so long back as the year 1400; the gloves made at that time being chiefly buck and doe skin. Scotland has not maintained the position which this priority would seem to indicate; for, with the exception of a few at Dundee and Montrose, there are hardly any gloves now made in that country.

In London the glovers were incorporated by Charles I. in 1638: although they had armorial bearings so long back as the year 1464. In the time of Charles I. the glovers of London carried on an important trade; and it was partly to remove certain abuses which had gradually crept into the occupation that the charter was given. The preamble, after stating that a petition had been received from the glovers of the metropolis, proceeds in the following curious strain :—"We have been informed that their families are about four hundred in number, and upon them depending above three thousand of our subjects, who are much decayed and impoverished by reason of the great confluence of persons of the same art, trade, or mystery into our said cities of London and Westminster, from all parts of our kingdom of England and dominion of Wales, that, for the most part, have scarcely served any time thereunto, working of gloves in chambers and corners, and taking apprentices under them, many in number, as well women as men, that become burdensome to the parishes wherein they inhabit, and are a disordered multitude, living without proper government, and making *naughty and deceitful gloves*." It is then stated that the reputation of English glovers had been injured abroad by these interlopers; and finally, the London company is endowed with the enormous power to "search for and destroy bad or defective skins, leather, or gloves."

Deer and sheep-skin gloves were the kind principally made in London in Charles's time; but after the introduction of kid gloves into England, the London makers took up that branch, and have maintained eminence in it to the present day. It was estimated eight or ten years ago, that there were about sixteen hundred glove-makers, men and women, in London, who made fifty thousand dozen pairs annually.

The city of Worcester has gained great reputation for its gloves. This branch of manufacture is known to have existed there for two hundred and seventy years; and the glovers of the city were incorporated in 1661. Beaver-gloves (made of leather dressed with oil) used to be made here, but when these began to get nearly out of fashion, the manufacturers took up the manufacture of 'tawed' or alumed leather-gloves (of which kid is an example) in greater quantities than before. A few years ago the produce of Worcester and its vicinity was estimated at so large a quantity as nearly half a million dozen pairs annually, the value of which was nearly four hundred thousand pounds.

The glove-trade of Worcester, in its general arrangements, is very interesting. The master-manufacturers were estimated in 1832 at a hundred and twenty; and the operatives, including men, women, and children, at thirty thousand. But it must not be supposed that this large number inhabit the city of Worcester: there are, on the contrary, only a small number of glove-makers within the city; the bulk of them being scattered throughout the villages lying ten or a dozen miles on every side of it. The sewing of a pair of gloves requires so little preparation or arrangement, that an humble cottager can carry on the occupation in her own poor dwelling; while her husband, and perhaps her children, are at work in the fields or the farm-yard.

If we trace a pair of Worcester kid-gloves through their progress of manufacture, we shall see the details of the system followed. In the first place the leather, whether it be real kid, or 'imitation kid' made of lamb's-skin, is generally prepared in London, by some one of the many leather-dressers of Bermondsey; or, in some cases, the skins undergo the earlier processes of dressing in Bermondsey, and are then dyed, softened, and brought to a finished state by the master-manufacturer at Worcester. Many of the Bermondsey leather-dressers have agents in Worcester, to transact the dealings with the master glovers. The dressed skins are cut out in the workshop of the master, generally by means of large shears; the workman shaping the various pieces partly by guides and partly by the accuracy of his eye and hand. The thumb-pieces, the pieces to form the sides of the fingers, &c., all of which have certain technical names, are cut out with much rapidity, and bound up in small parcels, each parcel containing the necessary pieces for a dozen pair of gloves. Some manufacturers employ a cutting-machine, for giving the shape to each piece of leather by one descent of a cutting-edge; but we believe that the use of such a machine is rather an exception than a rule.

If the operative glovers live in or near Worcester, they go to the house of the manufacturer, receive the leather in small parcels, and carry it home to work up into gloves. But if they live ten or twelve miles out, a curious system is followed. The manufacturer sends an agent, once a week, or as often as may be deemed necessary, who opens a temporary warehouse at a public-house or at some hired room, and there meets all the humble workpeople who live within a few miles on every side. Each operative brings to the agent the gloves which he or she may have made since the last visit, receives the money-payment for the labour, and takes home another supply of leather to be worked up before the period of the next visit. Precision, certainty, and economy of time result from this plan. There is one great focus at Worcester; around which, at a distance of several miles, are minor foci. These smaller foci draw towards themselves the labour of a little circle each, and then yield them up to the central mart, whence the capital comes which sets all this productive industry into action.

Following one of the operative glovers to her home, we shall see that her only working implement, besides needles and thread or silk, is a clasp or clam which she holds between the feet and knees, and which acts as a pincer or vice to retain the glove in a fixed position during the process of sewing. In some few cases, however, a little instrument is employed for ensuring regularity in the stitches: this is a kind of brass comb, or notched plate, whose notches guide the needle. If we notice a few pairs of gloves, different in kind and price, we shall see that different appearances are presented by the threads; but all are produced by a kind of stitching or sewing precisely the same as that by which many other garments are made. Some females confine their attention to sewing the different pieces together; some work the ornamental stitching at the back of the glove; while others finish the top.

Under many an humble roof in the outskirts of Worcester may be seen a mother and her daughters thus employed. It is, under the average state of trade, a close day's work which will yield a shilling to the workwoman. The occupation is somewhat analogous in this respect to the straw-plait working of Bedfordshire and Buckinghamshire, which, like it, is carried on in the cottages. It is possible that we might be able to construct a sort of map of cottage-industry in England, consisting of certain centres, around which were grouped the cottagers engaged in some one occupation. Thus taking Worcester as a centre for the glove-trade, and Redditch as another for the needle-trade, we should find these two groups meeting each other in some intermediate point; and we should perhaps find a third group filling or partially filling the space between those of Worcestershire and those of the straw-plait counties.

There are several towns in England which now possess, or have at former times possessed, a reputation for glove-making. Woodstock gloves have been known ever since the time of Queen Elizabeth, who is said to have received a pair during one of her 'progresses.' They are made of English deer, sheep, and lambs' skins, and have been much admired for the beauty of their workmanship. Hexham gloves were formerly much worn, especially as gauntlets to suits of armour; but in modern times the trade has declined, probably from the stout and unwieldy nature of the gloves: the Hexham tan-gloves were made of tanned sheep-skins. A kind of glove, made of native sheep and lamb skins, was formerly much esteemed under the name of York tans, being made to a considerable extent in that city. The Hereford beaver-gloves were similarly in repute, and at one time employed three thousand persons in the manufacture. At Ludlow and at Kington, in past times, large quantities of gloves were made, but the number has now greatly declined. A similar remark may be made in reference to the Leominster gloves. Yeovil is one of the most important of our glove towns. The number of pairs made there has been estimated at three hundred thousand dozens annually; and the number of operative glovers within the district of which Yeovil is the centre, twenty thousand. The finer kinds of gloves, as well as military gloves, are made here; formerly English skins were wholly used, but now Spanish, Italian, and German lamb-skins are the principal kinds employed. Martock, Milborne Port, Glastonbury, Wells, Shepton Mallet, and Torrington, are all centres to a limited amount of glove-making.

There are two circumstances which have made a notable change in the glove-trade of late years, viz. the introduction of cotton or 'Berlin' gloves, and a repeal of the prohibition to the importation of French gloves. With respect to the former cause, an entirely new branch of manufacture has sprung up, chiefly in Nottingham and Leicester, where vast quantities of cotton-gloves are now made. As to the second cause, the same complaints have been made as in most other instances of the repeal of prohibition; the ruin of the home-trade has been foretold and the most gloomy thoughts entertained by many engaged in the leather-glove manufacture. There is, however, in Mr. M'Culloch's 'Commercial Dictionary,' a paragraph on this subject so important, that, though rather long, we will quote it entire:—"The importation of leather-gloves and mitts was formerly prohibited under the severest penalties. This prohibition had the effect, by preventing all competition and emulation with the foreigner, to check improvement, and to render British gloves at once inferior in quality and high in price. This system was, however, permitted to continue till 1825, when the prohibition was repealed, and gloves allowed to be imported on payment of duties which, though high, are not prohibitory. This measure was vehemently opposed, and many predictions were made of the total ruin of the manufacture. But in this, as in every similar instance, experience has shown that the trade had not been really benefited, but that, on the contrary, it had been injured by the prohibition. The wholesome competition to which the manufacturers now felt themselves, for the first time, exposed, made them exert all their energies; and it is admitted on all hands that there has been a more rapid improvement in the manufacture during the last half-dozen years than in the previous half-century. There is still, no doubt, a great deal of complaining of a decay of trade among the leather-glove manufacturers; but we are assured that if there be any real foundation for their complaints, it is ascribable far more to the growing use of home-made cotton-gloves than to the importation of foreign gloves; and had it not been for the improved fabric and greater cheapness of British leather-gloves that has grown out of the new system, it is abundantly certain that cotton-gloves would have gained still more rapidly on them. In point of fact, however, it does not appear that there has been any falling off in the leather-glove trade. On the contrary, the fair inference seems to be that it has materially increased; at all events there has been a very considerable increase in the number of skins brought from abroad to be used in the manufacture, and consequently in the number of pairs of gloves produced from such skins; and there is no reason for thinking that it is at all different with the other departments." This was written about five or six years after the admission of foreign gloves was permitted.

THE END.

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# BRITISH MANUFACTURES.

## SERIES VI.

BY GEORGE DODD.

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# BRITISH MANUFACTURES.

## SERIES VI.

### INTRODUCTION.

The manufactures which will occupy attention in the present volume, the last of the series, are such as belong to one or other of two classes peculiarly characteristic of the present times—BOOKS and TRAVELLING.

It is singular to trace the progressive advancement in these two important agents of civilization and social improvement. The manuscript rolls and papers of early days; the more conveniently formed manuscript books of the monastic times; the first humble stage of printing by fixed wooden types; the substitution for these of moveable types; and the gradations of excellence from the first simple "printing-press," to the wondrous "printing-machine" of modern days,—all meet with something like a parallel in the mechanical aids which have successively and successfully been brought to bear upon the modes of travelling. The first rudely formed canoe; the clumsy barge; the lighter canal "fly-boat;" the majestic ship, with its admirable network of spars, sails, and ropes; and lastly the steam-boat, literally screwing its way across the Atlantic—are nearly analogous stages in the progress of water-travelling. And we shall find that travelling by land may come within the same remark. The roughly hewn vehicles of half-civilized nations; and the progression in our own country from the heavy waggon and the clumsy cart to the light chaise, the elegant carriage, the omnibus and the cabriolet, the well appointed stage-coach, the dashing "mail" rolling on at the rate of twelve miles an hour, the railway locomotive producing its marvellous results, and the railway atmospheric system, bidding fair even to eclipse the locomotive—all form a series, of which the two extremes are as far apart as manuscript-copying is from machine-printing.

Some of the more striking among the manufactures connected with these subjects will come successively under notice: many of the minor ones must of necessity be excluded.

It is proper to remark, that the details concerning printing and paper-making are mainly founded (with slight alterations) on four papers in the 'Penny Magazine' (Nos. 96, 101, 107, 112), written by a different hand from the rest of this volume. As those papers are the result of a personal knowledge and inspection of the processes, it has been considered advantageous to incorporate them here; and permission so to do has been obtained from the author, Mr. Knight.

# CHAPTER I.

## PAPER-MAKING; PARCHMENT AND VELLUM; ANCIENT MANUSCRIPTS.

THE art of paper-making has most materially influenced, and has been materially influenced by, the change from manuscript-copying to mechanical printing. A few details illustrative of this point will fittingly precede a description of the paper-manufacture; and other details will be found in two former numbers of the 'Weekly Volume.'*

William Caxton, the first English printer, at the end of the first book which he printed, uses the following remarkable words:—

"Thus end I this book, which I have translated after mine author, as nigh as God hath given me cunning; to whom be given the laud and praising. And forasmuch as in the writing of the same my pen is worn, mine hand weary and not steadfast, mine eyes dimmed with overmuch looking on the white paper, and my courage not so prone and ready to labour as it hath been, and that age creepeth on me daily and feebleth all the body; and also because I have promised to divers gentlemen and to my friends to address to them as hastily as I might this said book: Therefore I have practised and learned, at my great charge and dispense, to ordain this said book in print, after the manner and form as ye may here see. And (it) is not written with pen and ink as other books be; to the end that every man may have them at once. For all the books of this story named the 'Recule of the Histories of Troyes,' thus imprinted as ye here see, were begun in one day, and also finished in one day."

---

* 'William Caxton, the first English Printer.' 'Capital and Labour.'—Both written by the Editor of the 'Weekly Volume.'

In this passage we find most of the conditions expressed which mark the superiority of the invention of printing over the old mode of multiplying books by the pen. The transcriber of a manuscript had to contend with the weary hand and the dim eye; he could not satisfy the wishes of "divers gentlemen" by producing his book "hastily;" and, above all, he could not meet the instant demand for copies of an admired production, by allowing every man to "have them at once." The slow process by which he worked was necessarily an expensive process: and thus the written books were immoderately dear; and so much importance was attached to them as property, that in many cases a volume was conveyed from the seller to the purchaser by legal assignment. On the contrary, the printer, after certain processes had been gone through which were equivalent to the labours of transcribing three or four copies, could produce as many books as he pleased; and as far as taking off the impressions was concerned (to which the old printers peculiarly applied the name of their art), a small book, such as that first printed by Caxton, might be "begun in one day, and also finished in one day."

The process of printing, when compared with that of writing, is unquestionably a cheap process; provided a sufficient number of copies of any particular book are printed, so as to render the proportion of the first expense upon a single copy inconsiderable. If, for example, it were required, even at the present time, to print a single copy, or even three or four copies, only of any production, the cost of printing would be greater than the cost of transcribing. It is when hundreds, and especially thousands, of the same work are demanded, that the great value of the printing-press in making knowledge cheap is particularly shown. It is probable that the first printers did not take off more than two or three hundred, if so many of their works; and, therefore, the earliest printed books must have been still dear, on account of the limited number of their readers. Caxton, as it appears by a passage in one of his books, was a cautious printer; and required something like an assurance that he should sell enough of any particular book to repay the cost of producing it. In his 'Legends of Saints' he says, "I have submysed (submitted) myself to translate into English the 'Legend of Saints,' called 'Legenda aurea' in Latin; and William, Earl of Arundel, desired me—and promised to take a reasonable quantity of them—and sent me a worshipful gentleman, promising that my said lord should during my life give and grant to me a yearly fee, that is to note, a buck in summer and a doe in winter." Caxton, with his sale of a reasonable quantity, and his summer and winter venison, was more fortunate than others of his brethren, who speculated upon a public demand for books, without any guarantee from the great and wealthy. Sweynheim and Pannartz, Germans who settled in Rome, and there printed many beautiful editions of the Latin Classics, presented a petition to the Pope, in 1471, which contains the following passage:—"We were the first of the Germans who introduced this art, with vast labour and cost, into your holiness' territories, in the time of your predecessor; and encouraged by our example, other printers to do the same. If you peruse the catalogue of the works printed by us, you will admire how and where we could procure a sufficient quantity of paper, or even rags, for such a number of volumes. The total of these books amounts to 12,475—a prodigious heap—and intolerable to us your holiness' printers, by reason of those unsold. We are no longer able to bear the great expense of house-keeping, for want of buyers! of which there cannot be a more flagrant proof than that our house, though otherwise spacious enough, is full of quire-books, but void of every necessary of life."

For some years after the invention of printing, many of the ingenious, learned, and enterprising men who devoted themselves to the new art which was to change the face of society, were ruined because they could not sell cheaply unless they printed a considerable number of a book; and there were not readers enough to take off the stock which they thus accumulated. In time, however, as the facilities for acquiring knowledge which printing afforded, created many readers, the trade of printing books became one of less general risk, and dealers in literature could afford more and more to dispense with individual patronage, and rely upon the public demand.

It has been said, that "the bent of civilization is to make good things cheap." There can be no doubt whatever that in all the processes in which science is applied the article produced is not only made better, but cheaper; and the more "the bent of civilization" leads to an extension of demand, the more will scientific knowledge and the division of labour be called into employment. But this is peculiarly the case in all *copying* processes, among which printing is the foremost. If a medal be executed for the use of one person only,—that is, if the whole expense of making the die be borne by one impression from the die,—the cost of one medal must be very great. But if many thousand copies of that medal be required, as was the case when the British soldiers who had been present at the victory of Waterloo each received a medal, the cost of the die, as apportioned to each medal, is scarcely anything. Now, instead of the die being executed in an inferior manner, when twenty thousand impressions are to be taken from it, it is probable that the workmanship will be very superior to that of the die which is only to produce one medal; for the co-operation of numbers allows a larger sum to be expended in the first cost of the die, without the price of each impression being sensibly affected by that cost. It is the same with the copying process of printing.

In the petition of Sweynheim and Pannartz to the Pope, which we have already quoted, one passage shows that the demand for paper, which had been created by the new art of printing, was supplied with difficulty. "If you peruse the catalogue of the works printed by us, you will admire how and where we could procure a sufficient quantity of paper, or even rags, for such a number of volumes." The total of their books amounted to 12,475 volumes. Now, as it was estimated, ten or twelve years ago, that the paper fitted for printing and writing, made in this country yearly, amounts to more than fifty million pounds, or *two thousand* times as much as that alluded to by the German printers, we may well make it a subject of marvel how such a quantity of rags can be obtained.

In early times, no such material as paper was known. Palm-leaves, the inner bark of trees, waxed tablets on which letters could be traced by a sharp point, skins, thin sheets of lead, linen cloth—all were used as thin leaves on which writing could be received; but the maceration of rags into a pulp, and the manufacture of these into thin sheets of paper, were a comparatively modern improvement.

The Egyptian *papyrus*, much used for this purpose, was a kind of rush or reed growing on the banks of the Nile: the reed was formed of a number of distinct scales or sheathings; and each one of these, when carefully peeled off, and further prepared, became a leaf capable of serving as paper. The early transcribers did not form the leaves into a book, but sewed them edge to edge, and coiled them up into a roll. The bamboo, and other species of plants somewhat similar in character, were used by other nations as paper, when separated into thin pellicles.

The use of *parchment* and *vellum* was a later stage. The former of these two materials is made from the skin of the sheep, and the latter from the skin of the young calf. The skins are stripped of their wool, and then undergo a long series of processes, in which they are scraped and washed many times, until reduced to the state of a very fine smooth filament. Vellum has the same general character as parchment, but is finer and better. In the early days, when a skin of parchment was regarded as a valuable commodity, transcribers used occasionally to scratch or rub out a writing on parchment, for the purpose of writing something else in its place. Many old parchments, now containing monkish legends, are believed to have once contained something much more valuable, written in ages long anterior. Indeed it is said that the writing materials employed by the transcribers of the middle ages included a peculiar kind of knife, which was employed to scratch out the writing on some old parchment manuscript; the parchment was then rubbed over with the pumice-stone to prepare it for being again written on. The parchments so re-written were called "*palimpsests;*" and in some curious specimens, where the former writing was not wholly effaced, it can be perused distinct from the more modern writing.

The cheap rate at which, in modern times, paper can be made from rags, otherwise useless, has rendered all such proceedings unnecessary; and we may now watch the very curious train of processes whereby this paper is made.

The material of which the leaves of the book, now in the reader's hand, were formed, existed, a few months ago, perhaps in the shape of a tattered frock, whose shreds, exposed for years to the sun and wind, covered the sturdy loins of the shepherd watching his sheep on the plains of Hungary;—or it might have formed part of the coarse blue shirt of the Italian sailor, on board some little trading vessel of the Mediterranean;—or it might have pertained to the once tidy *camicia* of the neat straw-plaiter of Tuscany, who, on the eve of some festival, when her head was intent upon gay things, condemned the garment to the rag-merchant of Leghorn; or it might have constituted the coarse covering of the flock bed of the farmer of Saxony, or once looked bright in the damask table-cloth of the burgher of Hamburg; —or, lastly, it might have been swept, new and unworn, out of the vast collection of the shreds and patches, the fustian and buckram, of a London tailor,—or might have accompanied every revolution of a fashionable coat in the shape of lining—having travelled from St. James's to St. Giles's—from Bond Street to Monmouth Street—from Rag Fair to the Dublin Liberty—till man disowned the vesture, and the kennel-sweeper claimed its miserable remains. In each or all of these forms, and in hundreds more which it would be useless to describe, this paper a short time since might have existed.

The rags of our own country do not furnish a fifth part of what we consume in the manufacture of paper. France, Holland, and Belgium prohibit, under severe penalties, the exportation of rags, because they require them for their own long-established manufactories. Spain and Portugal also prohibit their exportation. Italy and Germany furnish the principal supplies of linen rags, both to Great Britain and the United States. They are exported from Bremen, Hamburg, Rostock, Ancona, Leghorn, Messina, Palermo, and Trieste. They arrive in our ports in closely packed bags, containing each about four hundredweight, which, according to the respective qualities of the rag, are marked S P F F, S P F, F F, F X, and F B. There are many varieties of rag even in these divisions; and their qualities are pretty clear indications of the state of comfort and cleanliness in particular districts and countries. The linen rags of England are generally very clean, and require little washing, and no bleaching, before they are ground into pulp; the Sicilian rags, on the contrary, are originally so dirty, that they are washed in lime before they are fit for the foreign market. The greater portion of the rags from the north of Europe are so dark in their colour and so coarse in their texture, that it is difficult to imagine how they could have formed part of any inner garments; while those, on the other hand, which are collected at home, evidently belong to a people who are clothed in "fine linen" every day.

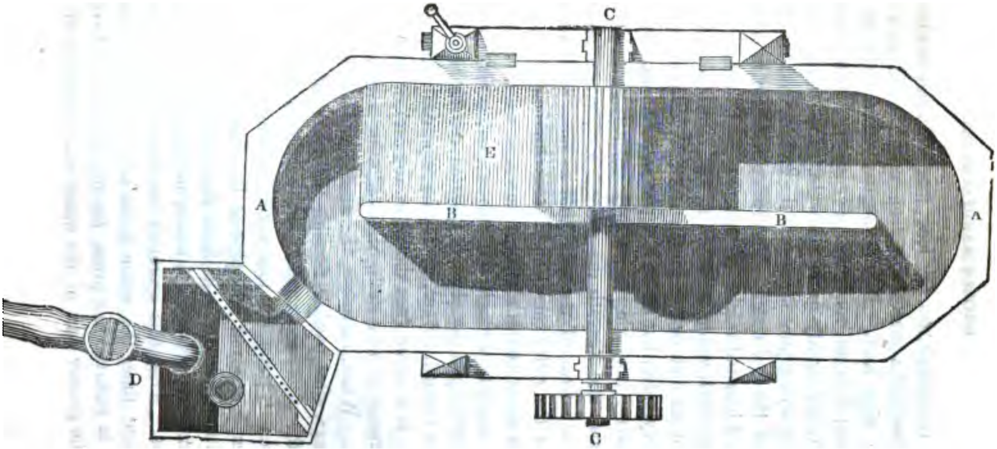
In a rightly managed paper-mill no substance but rags enters into the composition of first-class paper. Dishonest manufacturers have, indeed, employed plaster of Paris in large quantities; but we believe the practice is very generally discontinued. Many experiments have been made upon substances proposed as substitutes for rags in the manufacture of paper. The bark of the willow, the beech, the aspen, the hawthorn, and the lime, have been made into tolerable paper; the tendrils of the vine, and the stalks of the nettle, the mallow, and the thistle, have been used for a similar purpose; the bine of our own hops, it is affirmed, will produce paper enough for the use of England; and several patents have been granted for making paper of straw. The process of bleaching the coarser rags, so as to render them fit for the purposes to which only those of the finest qualities were formerly applied, will, however, render the use of these inferior substances unnecessary for many years. But the time may probably come when we shall obtain no rags from other countries. The advance of a people in civilization has not only a tendency to make the supply of rags abundant, but, at the same time, to increase the demand for rags. The use of machinery in manufactures renders clothing cheap; the cheapness of clothing causes its consumption to increase, not only in the proportion of an increasing population, but by the scale of individual expenditure; the stock of rags is therefore increasing in the same ratio that our looms produce more linen and cotton cloth. But then the increase of knowledge runs in a parallel line with this increase of comforts; and the increase of knowledge requires an increase of books. The principle of publishing books and tracts, to be read by thousands instead of tens and hundreds, has caused a large addition to the demand for printing-paper.

Paper-mills (in the south of England) are set in motion by water-power,—that is, they are placed upon some small stream, which, being dammed up, sets the wheels in motion, as in a flour-mill. In the north of England, where coal is abundant, paper-mills employ steam-power; and in the present mode of manufacturing paper, in which heat is essential, it is probable that the article can be produced at a lower rate by this process. A paper-mill moved by water-power is generally a very agreeable object. It is in most instances situated in some pretty valley, through which the little river glides; —and as it is important that the water (which is not only employed for turning the wheels, but for converting the rags into pulp) should be of the purest quality, the stream is generally one of those transparent ones which are so common in England—now bubbling over pebbly shallows, and now sleeping in quiet depths.

The first process in paper-making is strangely in contrast with the general appearance of cleanliness which distinguishes a paper-mill. In a long room, filled with dust, are several women employed in sorting and cutting rags. Each woman stands at a frame or table whose top is covered with wire: on her left is a quantity of rags; on her right, a box divided into three compartments. On a part of the table an upright knife, about a foot long, is fixed: this formidable instrument looks like the broken blade of a scythe. It is the business of the woman to sort and cut the rags. She spreads a few on the wire frame before which she stands; and as she shakes them, a great deal of the dirt passes through the wire to a box beneath. If the pieces are small enough —and they are required not to be larger than three or four inches square—she throws each piece into one of the compartments of the box on her right, according to its quality. If a piece requires to be cut, she draws it across the blade of the knife, by which it is instantly divided. She is particularly careful to put all seams by themselves; for the sewing thread, if not thoroughly ground, would produce filaments in the paper. These operations are performed with great rapidity. An active workwoman can sort and cut about a hundredweight a day. When cut and sorted the rags are weighed, and removed in bags containing each a hundredweight.

In looking at the operations of the rag-room, the first impression of the visitor is, that the rags which he sees are for the manufacture of the coarse brown paper which is used for so many commercial purposes. He cannot believe that the dingy bits of linen cloth, many of them originally of the colour of a sack, should become that beautiful fabric, a sheet of white paper. But so it is. This wonderful change is gradually brought about by very certain and simple processes. We leave the sorting-room, and are conducted to a shed, in which there are several large square chests filled with rags. We see the muddy-looking mass heaving up and somewhat agitated. Steam is being admitted into the chests; and here they are boiled with lime for a few hours. At the end of that period they are still very discoloured; but the inexperienced observer begins to have hopes that they may at least serve for *whited-brown* paper. From the washing-shed we are conducted into an upper room in the mill. We hear a deafening noise, and see that it is produced by the movements of a large horizontal wheel, which is connected with several oval cisterns, or troughs, about ten feet long, and four or five feet broad. These troughs, and the machinery within them, are technically called *Engines*: their uses are most important in the manufacture. Previous to their introduction into this country, which was about seventy years ago, the rags were first washed by hand;—then placed wet in close vessels till they became half-rotten;—and after the fibre was thus nearly destroyed, they were reduced to pulp, either by hammers in a mortar or by a cylinder grinding against the sides of a circular wooden bowl. All these operations were slow and expensive, and very destructive of material. In these engines, which wash, tear, and beat the rags, every particle is preserved; and the whole process, by the aid of machinery in making the sheet, is so rapid, that a bag of rags may easily leave the port of Hamburg on the first of the month, and be converted into paper—nay, printed upon and distributed through the United Kingdom by the first of the following month.

Into one of these engines, then, the boiled rags are first placed to be washed. If the white linen rags of England only are used, they are not boiled, but are at once placed in the washing-engine. The following wood-cut may assist the description:—


C
E
A
B
B
A
D
C

A is the trough, ten feet long, four and a half feet broad, and two and a quarter feet deep. It is made of wood, lined with lead. B is a longitudinal division of the engine; C is an iron roller, twenty-two inches in diameter, and twenty-six inches wide. D is an apparatus for conveying pure water into the trough, and for carrying off the foul water. The roller being set in motion, about a hundredweight of rags are put into the trough, and as much water is let in as will raise the whole to within an inch or two of the brim. The roller is not a plain cylinder, but its surface presents a number of bars, or knives, projecting more than an inch radially from its axis; and beneath the roller is a plate composed of bars, or knives, of the same kind as those of the roller. When the roller commences its revolutions, of which it makes about 160 in a minute, the rags are carried with great rapidity through the knives; and as the roller is depressed upon the plate, or elevated, are the rags drawn out, or bruised, or cut, as may be required. Above the roller is a cover (not shown in the cut), in which are two frames of wire cloth, communicating with the pipes at D. When, therefore, the whole mass is in agitation, the rags, after passing through the knives of the roller and the plate, are carried up the inclined plane of the division E; and the foul water, passing through the frames, is removed by a pipe at D, while a clear stream is continually pouring in from the same point. In this way the rags are bruised down, and washed, in the first engine. After this operation has been continued for a sufficient time, the water is let off; and the cleansed mass is removed to a press, for the purpose of driving out the greater part of the water which remains in it.

In this state, the foreign rags, though not white, are clean, and have somewhat the colour of the cloth called brown holland. The process of bleaching reduces every description of linen rag to a uniform whiteness; and if the operation is properly conducted, the quality of the fabric is uninjured. The rags, being removed from the press, are placed in a receiver or chamber made of wood, from which the external air is carefully excluded. Into this chamber are conveyed pipes, communicating with a retort, in which chlorine is formed, by the application of heat to a due proportion of manganese, common salt, and sulphuric acid. This part of the process is completed in a few hours. The rags are now white; but they have an intolerable smell. The subsequent operations of washing and bruising entirely purify them.

From the gas chamber the rags are again conveyed to the washing-engine, where they are driven round as before, till the chlorine is thoroughly forced out of them. They are then let off into the beating-engine, which is of the same construction as the washing-engine, except that the knives of the roller and the plate are closer together, and that the roller here is moved with more rapidity. In the washing-engine the motion of the rollers produces a harsh growling sound—in the beating-engine the noise is that of a loud humming, which is not unpleasant. Having been ground for several hours in this machine, the rags assume the beautiful appearance of pulp. In this state the preparation somewhat resembles milk. In this engine, the *size*, which is prepared from pieces of sheep-skins, and other animal substances, is sometimes introduced. In writing-paper the size is applied after the sheet is made.

From the last engine the pulp, now completely ready to be formed into paper, is conveyed by a valve to the chest. This is a large circular vessel, which will contain several engines-full of pulp, technically called *stuff.* The chest, which we shall presently describe in connexion with the *paper-machine,* is twelve feet in diameter by five in depth. An *agitator* constantly revolves round it, by which the stuff is kept from sinking.

We are now arrived at that stage of the process in which the sheet of paper is to be formed out of the stuff thus prepared. In some cases the sheet is made by hand in a mould; in others, by machinery. The paper of the present volume is, like most other printing-paper, made by the machine. But as a great deal of paper is still made by hand, it will be right that we should briefly describe that operation.

A vat is supplied with *stuff* from the chest already described; and that stuff is kept warm by a copper within the vat, to which heat is communicated by a steam-pipe. It is also agitated by machinery within. The workman forming the sheet, who is called a "vatman," is provided with two moulds. These are slight frames of wood, covered with fine wire. Fitting to each mould is a deckel, or moveable raised edging, which determines the size of the sheet. The vatman, putting the deckel on one of the moulds, dips it vertically into the stuff; and bringing it to the surface horizontally, covered with pulp, shakes it gently. It must be evident that this operation requires the greatest nicety, both in determining the general thickness of the sheet and in producing it of a uniform thickness throughout. The vatman then pushes the mould with the sheet towards his fellow-workman, who is called the "coucher;" and, taking off the deckel, applies it to the second mould, and proceeds as before. The coucher, who receives the first mould, having a heap of porous pieces of flannel by his side, called felts, turns the mould over upon a felt, upon which the sheet remains; and placing a felt on the sheet, he is ready to turn over another from the second mould. Thus the vatman and the coucher proceed, the one moulding a sheet of paper, and the other placing it upon felt, till they have made six or eight quires. The heap is then subjected to the action of a powerful press. The sheets, after this pressure, have acquired sufficient consistency to enable them to be pressed again by themselves. The felts are accordingly removed, and one sheet being laid upon another, the heap is subjected to a moderate pressure. The sheets are next parted; then dried, five or six together; next sized by dipping; again dried and pressed; examined to throw out any damaged sheets, or to remove knots; and, finally, put into quires and reams.

Passing now to the machine-made paper, it may be said that in the whole range of machinery there is, perhaps, no series of contrivances which so forcibly address themselves to the senses. There is nothing mysterious in the operation; we at once see the beginning and the end of it. At one extremity of the long range of wheels and cylinders we are shown a stream of pulp, not thicker than milk and water, flowing over a moving plane; at the other extremity the same stream has not only become perfectly solid, but is wound upon a reel in the form of hard and smooth paper. This is, at first sight, as miraculous as any of the fancies of an Arabian tale.

Aladdin's wonderful lamp, by which a palace was built in a night, did not in truth produce more extraordinary effects than science has done with the paper-machine. A visitor feels himself compelled patiently to watch the process for a long time before the mind can be divested of a vacant feeling of wonder, and prepared to understand the manifold arrangements by which these extraordinary effects are produced.

At one extremity of the machine is the chest, full of stuff or pulp. We mount the steps by its side, and see a long beam rolling incessantly round this capacious vessel, and thus keeping the fibres of linen, which look like snow-flakes, perpetually moving, and consequently equally suspended, in the water. At the bottom of the chest, and above the vat, there is a cock, through which we observe a continuous stream of pulp flowing into the vat; which is always, therefore, filled to a certain height. From the upper to the lower part of this vat, a portion of the pulp flows upon a narrow wire frame, which constantly jumps up and down with a noise resembling a cherry-clack;—this is called a sifter. Having passed through the sifter, the pulp flows still onward to a ledge, over which it falls in a regular stream, like a sheet of water over a smooth dam. Here we see it caught upon a plane, which presents an uninterrupted surface of five or six feet, upon which the pulp seems evenly spread, as a napkin upon a table. A more accurate inspection shows us that this plane is constantly moving onwards with a gradual pace; that it has also a shaking motion from side to side; and that it is perforated all over with little holes—in fact, that it is an endless web of the finest wire. If we touch the pulp at the end of the plane, upon which it first descends, we find it fluid; if we draw the finger over its edge at the other end, we perceive that it is still soft—not so hard, perhaps, as wet blotting-paper,—but so completely formed, that the touch will leave a hole, which we may trace forward till the paper is perfectly made. The pulp does not flow over the sides of the plane, we observe, because a strap, on each side, constantly moving, and passing upon its edges, regulates the width. After we pass the wheels upon which these straps terminate, we perceive that the paper is sufficiently formed not to require any further boundary to define its size;—the pulp has ceased to be fluid. But it is yet tender and wet; and we see that a wire cylinder, which presses upon its surface, leaves a succession of lines marked upon it in its passage. The paper, we perceive, is not yet completely off the plane of wire: before it quits it, another roller, which is clothed with felt, and upon which a stream of cold water is constantly flowing, subjects it to pressure. The paper has at length left what may be called the region of *Wire*, and has entered that of *Cloth*. A tight surface of flannel, or felt, is moving onwards with the same regular march as the web of wire. Like the wire, the felt is what is called endless—that is, united at the extremities, as a jack-towel is. We see the sheet travelling up an inclined plane of this stretched flannel, which gradually absorbs its moisture. It is now seized between two rollers, which powerfully squeeze it. It goes travelling up another inclined plane of flannel, and then passes through a second pair of pressing-rollers. It has now left the region of cloth, and has entered that of *Heat*. The paper, up to this point, is quite formed; but it is fragile and damp. It is in the state in which, if the machinery were to stop here, as it did upon its first invention, it would require (having been wound upon a reel) to be parted and dried as hand-made paper is. But in a few seconds more it is subjected to a process by which all this labour and time are saved. From the last pair of cloth pressing-rollers, the paper is received upon a small roller, by which it is guided over the polished surface of a large heated cylinder. The soft pulp tissue now begins to smoke; but the heat is proportioned to its increasing power of resistance. From the first cylinder, or drum, it is received upon a second, considerably larger, and much hotter. As it rolls over this polished surface, we see all the roughness of its appearance, when in the cloth region, gradually vanishing. At length, having passed over a third cylinder, still hotter than the second, and having been subjected to the pressure of a blanket, which confines it on one side, while the cylinder smooths it on the other, it is caught upon the last roller, which hands it over to the reel,—the perfect substance which the reader now holds in his hand. But there is no division in the paper thus formed; it is an uninterrupted roll of yard upon yard, which has no necessary termination but the power of reeling it. A supplementary machine receives it off the reel; and as it mounts upon the drum a circular knife cuts it into two breadths; while, having descended to a lower point, a series of sharp teeth, which strike against it within, divide it, by a stroke of invariable regularity, into the requisite lengths. The sheet of paper is now made. The process is as rapid as it is beautiful; for, from the commencement of the process, when the pulp flows out of the vat upon the web of wire, till the paper into which it is formed is received upon the reel, somewhat less time than two minutes is occupied. The web of wire travels at a rate which produces twenty-five superficial feet of paper per minute.

In all machinery which takes the place of handiwork there must be certain points of resemblance or of contrast between the one process and the other, which are instructive to examine. Up to the formation of the pulp or stuff, the process of paper-making is the same, as we have seen, whether the pulp is to be converted into paper by hand or by machinery. The vatman dips his mould into the vat, and produces a soft sheet of paper, of uniform thickness, by that delicacy of touch whose perfection constitutes the best workman. But as this regularity essentially depends upon manual dexterity, it must necessarily be incomplete. It may vary with the health of the workman; with the temperature in which he is placed; with the time of day at which he labours. In the machine the thickness of the paper is regulated by the quantity of stuff which is allowed to flow out of the chest; and all that is required to render this thickness invariable, is an invariable speed in the motion of the machine. If the web of wire travel at a rate that will make twenty-five feet of paper a minute, and the chest discharges (we will say) five gallons of stuff in the same period, there can be no change in the thickness of the sheet. But let the machine move with greater speed,—let the web travel at the rate of making thirty feet in a minute, while the chest still discharges only five gallons of stuff,—and the paper will be thinner by one-fifth. Again, let the pace of the machine be unaltered, but let the chest discharge ten gallons instead of five in the minute, and it is manifest that the thickness of the sheet will be doubled. So far the machine has an advantage over the workman. It goes on to copy his movements. As the water drains through the web of wire in its onward passage, leaving the pulp upon the surface, the machine imitates the action of the vatman, who holds his mould for a space over the vat; and as he gently shakes the mould to distribute the pulp evenly over its surface, so has the web a shaking motion, from side to side, to produce the like effect. The vatman loses none of his material; for every particle of unused fibre returns through the mould into the vat, with the sized water, with which the stuff is often prepared: the machine is equally economical;—for all that drains through the wire web is collected in a cistern, where the web returns, and is lifted up and discharged again into the vat. As the vatman also defines the size of his sheet by the deckel fitting to the mould, so the deckel-straps of the machine, constantly moving onward, and pressing tightly upon the edges of the moving pulp, regulate its width. In hand-made paper that sort which is technically called laid, that is, marked with lines, receives this appearance from wires crossing the web. The same appearance, if it be thought desirable, is imparted in the machine by a wire cylinder, called a "dandy." The coucher, whose functions we have already described, removes the sheet made in a mould from the vatman, and places it between two felts. The same absorption is caused in the machine, by the sheet travelling over a large felted surface, and passing between felted rollers. These rollers, be it observed, do the work also of the pressure to which the hand-made paper is subjected before it is dried.

So far the operations of making paper by hand and by machine have a certain general resemblance. But here the parallel ceases. The beautiful contrivance of drying and smoothing the sheets by hot cylinders is a modern application to the machine; and it certainly gives the process a perfection which is unattainable in the system of drying each sheet, either by exposure to the atmospheric air or to steam, upon poles. Mr. Fourdrinier, who perfected the machine as far as making the paper upon an endless web of wire, and pressing it in various felts, did not attempt the great modern improvement of drying the sheets without removal. Each cylinder is heated by steam, from a pipe communicating with its hollow part within. The heat, as we have mentioned, is gradually imparted to the paper. If the first cylinder which receives the sheet be taken at the temperature of 80°, the second would be 100°, and the third 120°.

The cutting-machine, which may or may not be applied to the paper-making machine, is an extremely beautiful contrivance, invented by Mr. Edward Cowper. Its object is chiefly to save material. It was usual, after a certain quantity of paper had been reeled, to cut it through while upon the reel. But it is evident that the sheets would consequently be irregular in their size, so that the inner part of the roll, when cut, might be an inch or two smaller than the outer part, according to the quantity reeled.

Mr. Dickinson, one of the most ingenious and successful manufacturers of paper in the kingdom, has constructed machines differing essentially from those of Fourdrinier's invention, as regards the formation of the pulp into paper upon the web of wire. This machine is thus briefly described in Dibdin's 'Bibliographical Decameron:'—"Mr. Dickinson employs a hollow cylinder, the surface of which is pervious, and is covered with woven wire; and this revolves in a vat of pulp, though not completely immersed; but by the axis, which is a hollow tube, there is a communication from some internal apparatus to a pair of air-pumps, and by their action the paper is formed, and made to adhere to the cylinder, and afterwards detached from it to an endless cloth, which conducts it to the pressing-rollers. The pulp for this machine is much more dilated than for any other mode of making paper, and therefore admits of the fibres which compose it being longer, which has a beneficial effect with regard to the texture of the paper, and renders it better adapted to receive a clear and distinct impression."

When the sheets of paper, completely formed and cut by the process we have described, are taken from the machine-room, they are subjected to a very careful examination. This work is performed by young women, whose business it is to remove every knot or speck in each sheet, and to lay aside those which have any rent or hole. The sheets, thus finished, are next subjected, in their full size, to the action of a powerful press. They are then cut round the edges, by what is called a plough; for it is essential to the beauty and regularity of printing, that the edges of the paper should be perfectly smooth. The open sheets are then counted into quires of 24 sheets; then folded in quires; then put into reams of 20 quires; then pressed in reams; and, lastly, tied up in wrappers.

We have already mentioned that the web of wire in the paper-machine travels at a rate to produce twenty-five superficial feet of paper per minute. In a working-day of ten hours, 15,000 feet will consequently be produced.

## CHAPTER II.

### ENGRAVED WOOD-BLOCKS AND TYPES; TYPE-FOUNDING.

FROM paper, our attention may fittingly be transferred to the means whereby printed devices or characters are impressed upon the paper.

Very early in the fifteenth century,—somewhere between 1400 and 1430,—an art was either discovered or introduced in Europe, which eventually conducted to the more important art of printing from moveable types. The invention to which we allude was that of taking impressions from lines cut in relief on blocks of wood. It is unnecessary here to enter into the details of a long controversy amongst antiquaries, as to whether engraving in wood was not practised in Italy a century earlier:—nor into the multifarious evidence of the Asiatic origin of this art. It is enough to state, that it is established beyond doubt that, in the first quarter of the fifteenth century, engraving on wood was applied to the multiplication of copies of designs which were in demand amongst the people of Italy and Germany. This demand, which very soon called into existence a considerable number of workmen, was addressed to two objects of a very opposite character,—books of devotion, and playing cards. The representations of saints and of Scriptural histories, which the limners in the monasteries had for several centuries been painting in their missals and bibles, were copied in outline; and being divested of their brilliant colours and rich gilding, presented figures exceedingly rude in their want of proportion, and grotesque in their constrained and violent attitudes. But they were nevertheless highly popular; and as the pictures were accompanied with a few sentences from Scripture, they probably supplied the first inducement to the laity to learn to read, and thus prepared the way for that diffusion of knowledge which was to accompany the invention of printing from moveable types. Again, for somewhat more than a century preceding the period of which we are speaking, playing-cards had become the common amusement of the noble and wealthy. The cards, like the missals, called forth the art of the limner; and the king, the knight, and the knave (the characters of the early cards), were rich with crimson and purple, oftentimes painted on a golden ground. Gambling, like many other vices and follies, descends from the great to those below them in the social scale; and it is easy, therefore, to conceive that the followers of courts and of camps, and the artisans and dealers in the towns, seeing the amusement which their superiors derived from these painted bits of paper or parchment, would be anxious to possess the same means of excitement in their hours of idleness. The art of wood-engraving was ready to supply the extended demand for playing-cards. The outline of the figure was cut in relief upon a block; and the coloured parts were afterwards added by the pencil. In Mr. Singer's elaborate and interesting 'History of Playing Cards' there are many fac-similes of the early cards.

It appears that the impressions of the engraved cards, as well as of most of the earlier block-prints, were taken off by friction. This is the mode by which, even at the present day, wood-engravers take off the specimen impressions of their works, called proofs. The Chinese produce their block-books in a similar manner, without the aid of a press.

In the collection of Earl Spencer there is a very curious print from a wood-block, representing St. Christopher carrying the infant Saviour. This print bears the date 1423. It is probably not the earliest specimen of the art; but it is the earliest undoubted document which determines with precision the period when wood-engraving was generally applied to objects of devotion. In a very few years from the date of this print, the art was carried onward, as we have mentioned, to a more important object—that of producing a *book* of popular instruction. The Bible, as is well known, could only at this time be obtained in manuscript, at a very heavy cost; such as would purchase a considerable estate in those days. It was thought that a selection of subjects from the Bible, with appropriate texts, both engraved upon wood, might be acceptable to the common people. Such a book was produced somewhere between the year 1430 and 1450, and was called 'Biblia Pauperum'—the Bible of the Poor. This very rare book consists of forty leaves of small folio, each of which contains a cut in wood, with extracts from the Scriptures, and other illustrative sentences. It was followed by others of a similar character, the most remarkable of which is called 'Speculum Salutis'—the Mirror of Salvation. In this performance the explanations of the text are much fuller than in the 'Biblia Pauperum;' and it is remarkable that, in one of the editions, part of the text is obviously printed from blocks, and part from moveable types. In addition to these works, wooden blocks were also used to print small manuals of grammar, called Donatuses, which were used in schools.

Imitating the manuscript books, the first printers chiefly employed the wood-engraver upon initial letters; and sometimes the pages of their works were surrounded by borders which contained white lines or sprigs of foliage upon black ground. If a figure or group of figures was introduced, little more than the outline was first attempted. By degrees, however, endeavours were made to represent gradations of shadow; and a few light hatchings, or white dots, were employed. All cross-hatchings, such as characterize a line engraving upon metal, were carefully avoided by the early wood-cutters, on account of the difficulty in the process. Mr. Ottley, in his 'History of Engraving,' says that an engraver on wood, of the name of Wohlgemuth (who flourished at Nuremburg about 1480), "perceived that, though difficult, this was not impossible;" and in the cuts of the 'Nuremburg Chronicle' "a successful attempt was first made to imitate the bold hatchings of a pen-drawing." Albert Durer, an artist of extraordinary talent, became the pupil of Wohlgemuth; and by him, and afterwards by Holbein, wood-engraving was carried to a perfection which it subsequently lost, till its revival in our own country by Bewick. For more than a century and a half after the invention of printing in England, as well as in France, Holland, and Germany, wood-cuts were profusely employed in the illustration of books. Those who have seen copies of the original editions of those very popular English works, 'Holinshed's Chronicles' and 'Fox's Martyrs,' will perceive how attractive and really instructive wood-cuts were considered in the sixteenth and early in the seventeenth century.

The early history of wood-engraving clearly points out the successive steps in the perfection of the art of printing. The art of multiplying copies of drawings existed in Europe very early in the fifteenth century. It might have originated here, or it might have been copied from the Chinese; for Marco Polo, nearly a century earlier, had seen the paper-money of this people, on which "the principal officer, deputed by the Cham, smears with cinnabar the seal consigned to him, and imprints it upon the money, so that the figure of the seal, coloured in cinnabar, remains impressed upon it." However this may be, the use of carved blocks for the multiplication of copies of playing-cards and devotional pictures gave birth to a principle which has effected, and is still effecting, the most important changes in the world. These devotional pictures had short legends or texts attached to them; and when a text had to be printed it was engraved in a solid piece as well as the picture. The first person who seized upon the idea that the text or legend might be composed of separate letters capable of re-arrangement after the impressions were taken off, so as to be applied, without new cutting, to other texts and legends, had secured the principle upon which the printing art was to depend. It was easy to extend the principle from a few lines to a whole page, and from one page to many, so as to form a book; but then were seen the great labour and expense of cutting so many separate letters upon small pieces of wood or metal, and another step was required to be made before the principle was thoroughly worked out. This step consisted in the ready multiplication of the separate letters by casting metal in moulds. All these gradations were undoubtedly the result of long and patient experiments carried on by several individuals, who each saw the importance of the notion they were labouring to work out. It is this circumstance which has given rise to interminable controversies as to the inventors of printing, some claiming the honour for Coster of Haarlem, and some for Guttenberg of Mentz.

The following statement, from an early German Chronicle, is believed to be pretty exact as to the relative merits of those concerned in the matter :—" At this time, in the city of Mentz on the Rhine in Germany, and not in Italy, as some have erroneously written, that wonderful and then unheard-of art of printing and characterizing books was invented and devised by John Gutenberger, a citizen of Mentz, who having expended almost the whole of his property in the invention of this art, and on account of the difficulties which he experienced on all sides, was about to abandon it altogether; when, by the advice, and through the means, of John Faust, likewise a citizen of Mentz, he succeeded in bringing it to perfection. At first they formed (*i. e.* engraved) the characters or letters in written order on blocks of wood, and in this manner they printed the vocabulary called a 'Catholicon.' But with these forms (or blocks) they could print nothing else, because the characters could not be transposed in these tablets, but were engraved thereon, as we have said. To this invention succeeded a more subtle one, for they found out the means of cutting the forms of all the letters of the alphabet, which they called matrices, from which again they cast characters of copper or tin of sufficient hardness to resist the necessary pressure, which they had before engraved by hand. And truly, as I learned thirty years since from Peter Opilio (Schoeffer) de Gernsheim, citizen of Mentz, who was the son-in-law of the first inventor of this art, great difficulties were experienced after the first invention of this art of printing, for in printing the Bible, before they had completed the third quarternion (or gathering of four sheets), 4000 florins were expended. This Peter Schoeffer, whom we have above mentioned, first servant and afterwards son-in-law to the first inventor, John Faust, as we have said, an ingenious and sagacious man, discovered the more easy method of casting the types, and thus the art was reduced to the complete state in which it now is. These three kept this method of printing secret for some time, until it was divulged by some of their workmen, without whose aid this art could not have been exercised; it was first developed at Strasbourg, and soon became known to other nations. And thus much of the admirable and subtle art of printing may suffice—the first inventors were citizens of Mentz. These three first inventors of printing (videlicet), John Gutenberger, John Fust, and Peter Schoeffer his son-in-law, lived at Mentz, in the house called Zum Jungen, which has ever since been called the Printing Office."

The original type was very similar to that which is still used most generally in German books. This is called the Gothic character, while the ordinary type which we employ is known as Roman. It derived that name from the first printers who used it. namely, Sweynheim and

Pannartz, who, in 1467, executed in this type an edition of Cicero's 'Epistolæ Familiares,' at their office in Rome. The Italic type was the invention of Aldus Manutius, the first of a celebrated family of printers, who employed it not as we do—very sparingly in quotations, but in the execution of a series of small classical works intended for general perusal. The object which he had in view was the saving of space, as the Italic letters, from their peculiarity of form, are thinner than the Roman or the Gothic. It is said that in this character Aldus attempted an imitation of the hand-writing of the celebrated poet Petrarch. His printing-office was established at Venice in 1490.

The original attempts to preserve the whole process of printing a secret, and which, no doubt, continued for a long time under that state of things when every trade was denominated a mystery, led to the union of the letter-founder and the printer. The division of labour (the progress of which principle is at all times slow) was little understood at that period, when the weaver manufactured his own loom, and the farmer constructed his own rude plough. Schoeffer, one of the first German printers, was also the first letter-founder; and he was, moreover, a book-binder. The general term printing originally included every process necessary for the production of a book, from cutting the punch by which the matrix is sunk, to stamping the leather which covered the ponderous wooden lids of the treasured folio.

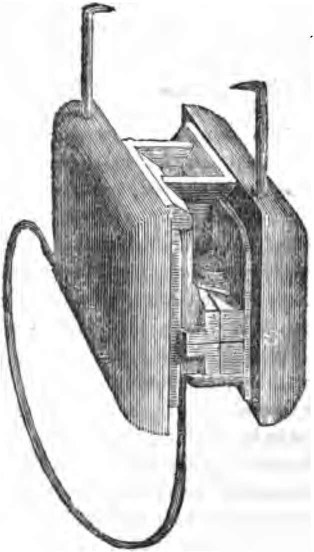
The English printers, from Caxton to John Day (who, in the year 1567, published a book of antiquities, in which he says that the Saxon characters were cut by himself), were all letter-founders. The trades, however, after this began to be separated, for we find a decree of the Star Chamber, in 1637, by which it is ordered that there shall be four founders of letters for the kingdom, and no more. The provisions of this absurd and oppressive decree were recognised in an act of 14th Charles II. (1674), which again restrained the number of master-founders to four; and by the same act the number of printers was limited to twenty. This, however, was only a provisional act, which appears to have been impossible of execution, like all other enactments which are directly opposed to the spirit of an age. The demand for knowledge had become so general that four founders and twenty printers were quite inadequate to the supply, whatever might be the opinion of Charles II. and his arbitrary court. The supply therefore went on. In a very curious book, written by Joseph Moxon, a mathematical-instrument maker, who also applied his mechanical knowledge to the art of letter-cutting, we are informed that, in 1686, "the number of founders and printers were grown very many, insomuch that, for the more easy management of typography, the operators had found it necessary to divide it into the several trades of the master printer, the letter-cutter, the letter-caster, the letter-dresser, the compositor, the corrector, the pressman, the ink-maker, besides several other trades which they take into their assistance, as the smith, the joiner, &c." Such a division of labour indicates the natural progress of an art towards perfection, and is indeed in itself a cause of that perfection. Moxon says that letter-cutting was a handy-work at that time, kept so concealed among the artificers of it, that he could not learn any one had taught it any other. Moxon himself, however, laid down mathematical rules for the formation of letters, but he does not appear to have attempted any improvement in their shape. In the reign of Anne we imported most of our type from Holland, where the letter-founders had succeeded in producing much more beautiful characters. At length, however, in 1720, William Caslon, an engraver of gun-locks and gun-barrels, having the credit of being a most ingenious artist, was employed by the 'Society for Promoting Christian Knowledge' to cut the punches for a fount of Arabic. His success led him to enter into the business of a letter-founder, in which undertaking he was assisted by Bowyer, the celebrated printer. In a very few years Caslon had rendered the English types superior to any in Europe; when the importation of foreign types ceased, and the founts of this ingenious founder became in demand on the Continent. The Caslon foundry is still continued by a descendant of the same name, with undiminished reputation.

The different sizes of types which are cast in this country are very considerable, varying from the smallest, called "diamond," of which 205 lines are contained in a foot, to those large letters which we see employed in placards, of which some single letters are three or even four inches high. The type which the reader is now perusing is called Bourgeois. We give a list of the names of these letters, with a scale which expresses their proportions, in the number of lines which each occupies in a foot:—

| | |
|---|---|
| Double Pica | 41½ |
| Paragon | 44½ |
| Great Primer | 51¼ |
| English | 64 |
| Pica | 71½ |
| Small Pica | 83 |
| Long Primer | 89 |
| Bourgeois | 102¼ |
| Brevier | 112½ |
| Minion | 128 |
| Nonpareil | 143 |
| Pearl | 178 |
| Diamond | 205 |

It is considered that the early printers and type-founders were very imperfectly acquainted with the proper composition of metal to be used. Lead, as being the most flexible metal, was principally employed; but then it was too soft for durability, and a portion of iron was consequently added. Antimony is now added to the lead, instead of iron. The smallest-sized types requiring the hardest metal, the alloy for these is twenty-five parts of antimony to seventy-five parts of lead; the proportions are varied for the larger sizes, so that in some only fifteen parts of antimony are used to eighty-five of lead.

In type-founding the *punch* and the *matrix* are important implements. The punch is of hardened steel, and exhibits upon its face a single letter, formed by hammering down the hollows, and filing up the edges, when the metal was in a softened state. With this tool an impression is struck into a piece of copper, about one inch and a quarter long, one-eighth of an inch deep, and wide in proportion to the size of the type to be cast. This is the matrix; which, after the die is sunk, is filed up to ensure the cast taken from it to be of the requisite depth, which process is called justifying. The *mould* is a most ingenious little instrument, represented in the woodcut in the next page. It is composed of two parts. The external surface is of wood; the internal of steel. At the top, as will be seen by the cut, is a shelving orifice, into which the metal is poured. The space within is as true as if it had been hollowed out of a single piece of steel; but nevertheless it is formed by the intimate union of the two parts of the mould, each part forming two of the four sides of the letter. It is not a matter of difficult adjustment to bring these sides together; it is the operation only of an instant. At the bottom of the mould, immediately under the orifice, is the matrix. This is held in its place by a metal spring, represented at the lower part of the cut; and every letter that is cast can only be loosened from the matrix by removing the pressure of the spring.



The metal is melted in a furnace-pot, and is cast in the mould by means of a remarkable and dexterous movement. The founder, having poured in the metal with his right hand, and returned the ladle to the melting-pot, throws up his left hand, which holds the mould, above his head, with a sudden jerk, supporting it with his right hand. It is this movement which forces the metal into all the interstices of the matrix; and without the movement the metal, especially in the smaller types, would not reach the bottom of the mould, for it could not force out the air by its specific gravity alone. But the observer will be equally astonished by the precision, as well as the rapidity of the whole operation, of pouring in the metal, throwing up the mould, unclosing it, and removing the pressure of the spring, picking out the cast letter, closing the mould again, and re-applying the spring to be ready for repeating the whole act. All these operations do not occupy the eighth of a minute, for the average number of letters cast in an hour is five hundred. We should observe, that a considerable piece of metal remains attached to the end of the type when it is turned out of the mould; also, that the mould is so constructed that it forms what is called a nick, or nicks, on the lower edge of the letter, by which the printer at once sees the right way to place it without looking at the face.

From the table of the caster the heap of types cast is from time to time removed by a boy to another table. It is his business to break off the superfluous metal; and this he does with such rapidity that the mode in which he operates can scarcely be followed by the eye. Some boys have been known to break off 5000 in an hour; the average number is 2000. This rapidity is the more remarkable, as the boy must seize the type, not upon the flat surface, but upon its edges, or he would otherwise break or bend it.

From the *breaking-off boy* the types are removed to the *rubber*. A round gritstone is before him, upon which is a heap of types. The fore and middle fingers of his right hand are armed with a piece of tarred leather; and he passes each side (not the edges) of the type smartly over the stone, turning it, of course, in the movement. This, again, is an example of wonderful rapidity; 2000 types are thus rubbed in an hour.

From the rubber the heap is conveyed to a boy whose business is to set up the types in lines, in a long shallow frame. The face of each must be uppermost, and the nicks outward. The rate at which this boy works is the same as the rubber.

When the types are once set up in lines, they are never again deranged till they are given out to be used by the printer. The long frame, filled with a single line of type, is removed to the *dresser*. By the application of other frames, he is enabled to dress or polish them on each edge; and, turning them with the face downwards, to channel-cut with a plane a groove in the bottom, so that they will stand steadily. It will at once be understood how necessary it is that every letter should be perfectly square and true, when it is considered that if they were not of uniform height, the impression could not be even; and that if there were the least deviation from a regular form, it would be quite impossible that, when 200,000 single letters are combined, as in one side of the 'Times' newspaper, they should hold together as they do, when wedged up, as securely as if that side were composed of one solid piece of metal.

Each letter being tied up in lines of convenient length, the proportionate numbers of each variety, small letters, points, capitals, small capitals, and figures, are selected; and the fount is ready for delivery to the printer.

## CHAPTER III.

### STEREOTYPE-FOUNDING; PRESS AND MACHINE PRINTING.

In a very curious set of prints by L. Galle, after the designs of Stradanus, a painter who flourished in the latter end of the sixteenth century, are represented many operations in the arts, as they were practised at that period. One of these represents a printing-office. On the right is the master printer, a grave, bearded personage, dressed in a fur-trimmed robe, apparently giving some directions to his workmen. These consist of several compositors, comfortably seated on cushioned stools; the dirk of one is in a sheath by his side, and the sword of another rests against a column. This ancient privilege of the compositors of all countries to wear swords still forms a matter of pride with the printers of the present day; for it affords a proof that their art was considered a liberal one, and that men of birth and education were accustomed to practise it. Near one of the compositors is an old man in spectacles, who is probably engaged in the business of a reader, which we shall have to explain. The men at work at the two rude presses, the farther one inking the types, and the other pulling down the screw which gives the impression, exhibit the mode then employed to work off the sheets, which must have been particularly slow. Altogether this print appears to show that in the ancient printing-offices there were few mechanical aids to labour.

There is a well authenticated story of an English clergyman, who taught himself the printing art, and carried it on with a persevering devotion to one object, of which we have no other example. This good man had projected a complete body of divinity in a great many volumes. He proposed his scheme to several publishers, but they all rejected it. He then caused copies of several volumes to be printed by subscription. This undertaking failed. He was determined, however, that his literary labours should not be deprived of that chance of immortality which the printing-press, to a certain extent, can bestow. He bought a few types, enough to set up two pages, and thus scantily provided, he undertook the wonderful task of printing, not a small tract, or even one goodly volume, but a great number of volumes. When his two pages were arranged, he printed off fourteen copies at a little press which he had established in his house. The types were then broken up to allow him to print the next two pages; and thus with a tortoise pace he printed away for some twenty years, and at last completed his work in twenty-six volumes. A copy of this remarkable production is said to exist in the British Museum.

The reader will at once comprehend, from this story, that the setting up of types, one by one, so as to produce syllables, words, sentences, paragraphs, chapters, and books, is essentially a slow operation—a much slower operation than copying with a pen—an operation which would be worthless except it were possible and desirable to produce many copies from the types thus set up. Taking the labour of the clergyman as worth fifty pounds a year, his work for twenty years would amount to one thousand pounds, and therefore each of his fourteen copies cost somewhat more than seventy pounds. If he had applied the same manual labour to any ordinary art, such as shoemaking for instance, in which manual labour is not much assisted by the division of employments and mechanical aids, he would probably have added a thousand pounds to the wealth of the community. *As it was*, he only amused himself.

The slow and profitless toil of this harmless recluse presents a striking contrast to the intense energy displayed in a large London printing-office. There are several establishments of this nature in which, we have no hesitation in saying, the division of labour is brought to such perfection, that a volume or volumes, containing as many words as the clergyman's thirty volumes, and, therefore, requiring as much of the compositor's labour, could be printed in a week.

In "composing," or arranging the types for printing, each man works at a sort of desk called a frame, and in most instances he has the desk or frame to himself. The frames project laterally from the wall;—at intervals there are large tables with stone tops, technically called imposing stones. The visitor will see no presses in the room with the compositors, as in the old Dutch print. These branches of business are separated, for the pressman pursues his noisy vocation, while the compositor is, or ought to be, silent. The one press in the composing-room is merely for taking off proofs. Nor will the visitor see an old gentleman in spectacles occupied merely in reading. The business of a reader requires even more silence than that of a compositor, and he, therefore, has a closet to himself.

Each *frame*, at which a compositor works, is constructed to hold two pair of *cases*. Each pair of cases contains all the letters of the alphabet, whether small letters or capitals, as well as points, figures, &c., &c. One of these pair of cases is occupied by the *Roman* letters, the other by the *Italic*. The upper case is divided into ninety-eight partitions, all of equal size: and these partitions contain two sets of capital letters, one denominated "full capitals," the other "small;" one set of figures; the accented vowels; and the marks of reference for notes. The lower case is divided into partitions of four different sizes; some at the top and ends being a little smaller than the divisions of the upper case; others nearer the centre being equal to two of the small divisions; others equal to four; and one equal to six. In all there are fifty-three divisions in the lower case. The inequality in the size of the cells of the lower case is to provide for the great differences as to the quantity required of each letter. According to the language in which it is used, one letter is much more frequently wanted than another; and the proportions required of each have been pretty accurately settled by long experience. As some of our readers may be curious to know these proportions as they apply to the English language, we subjoin the type-founder's scale for the small characters of a fount of letter of a particular size and weight.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| a | 8500 | h | 6400 | o | 8000 | v | 1200 |
| b | 1600 | i | 8000 | p | 1700 | w | 2000 |
| c | 3000 | j | 400 | q | 500 | x | 400 |
| d | 4400 | k | 800 | r | 6200 | y | 2000 |
| e | 12000 | l | 4000 | s | 8000 | z | 200 |
| f | 2500 | m | 3000 | t | 9000 | | |
| g | 1700 | n | 8000 | u | 3400 | | |

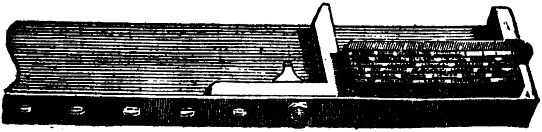
The proportion in which a particular letter is required, renders it necessary that the cells of the lower case should be arranged not as the letters follow each other alphabetically, but that those in most frequent use should be nearest the hand of the compositor. The point to which he brings the letters, after picking them up out of their cells, is not far removed from the centre of the lower case; so that in a range of about six inches, on every side, he can obtain the c, d, e, i, s, m, n, h, o, p, u, t, a, and r, the letters in most frequent use. The spaces, which he wants for the division of every word,

The Compositor.

lie close at his hand at the bottom of the central division of the lower case. It must be quite obvious that the man who contrived this arrangement saved a vast deal of time to the compositor. A stranger to the art is surprised at the accuracy with which a compositor dips his fingers into the box containing the letter which he requires. This surprise is generally connected with an opinion that the compositor would do his work more correctly if the boxes were labelled. A very inexpert performer upon the piano will, nevertheless, strike any one of the seventy-eight notes without making a mistake; and in the same way the youngest boy of a printing-office very soon learns the places of the letters without any difficulty.

Let us now for a little while follow the compositor in the progress of his work.

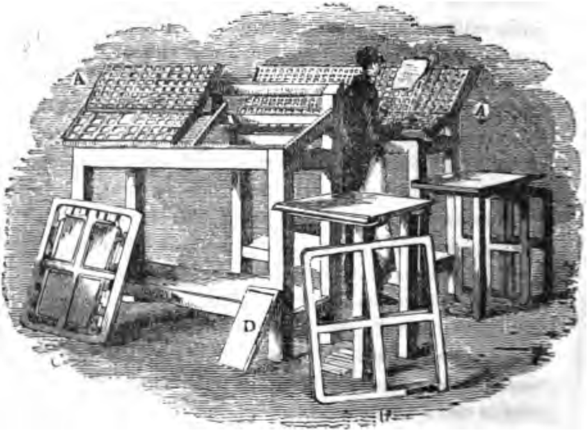
Standing before the pair of cases which contain the Roman letter, he holds in his left hand what is called a *composing-stick*. This is a little iron or brass frame, one side of which is moveable so that it may be adjusted to the required width of the page or column which the workman has to set up. It is made perfectly true and square; for without such accuracy the lines would be of unequal length. It is adapted to contain not more than about twelve lines of such type as the present.



Composing-Stick.

The copy from which the compositor works rests upon the least-used part of the upper case. The practised compositor takes in a line or two at a glance, always provided the author writes an intelligible hand—which virtue is by no means universal. One by one, then, the compositor puts the letters of each word and sentence into his stick, securing each letter with the thumb of his left hand, which is therefore continually travelling on from the beginning to the end of a line. His right hand goes mechanically to the box which he requires; but his eye is ready to accompany its movements. In each letter there is a nick, or nicks, which indicates the bottom edge of the letter; and the nick must be placed outwards in his composing-stick. Further, the letter must also be placed with the face upwards, so that two right positions must be combined in the arrangement of the types. If the compositor were to pick up the letter at random, he would most probably have to turn it in his hand; and as it is important to save every unnecessary movement, his eye directs him to some one of the heap which lies in the right position, both as regards the face being upwards and the nick being outwards. This nick is one of those pretty contrivances for saving labour which experience has introduced into every art, and which are as valuable for diminishing the cost of production as the more elaborate inventions of machinery. When he arrives at the end of his line, the compositor has a task to perform, in which the carelessness of the workman is greatly exhibited. The first letter and the last must be at the extremities of the line: there can be no spaces left in some instances, and no crowding in others, as we see in the best manuscript. Each metal type is of a constant thickness, as far as regards that particular letter; though all the letters are not of the same thickness. The adjustments, therefore, to complete the line with a word, or, at any rate, with a syllable, must be made by varying the thickness of the spaces between each word. A good compositor is distinguished by uniformity of spacing: he will not allow the words to be very close together in some instances, or with a large gap between them in others. His duty is to equalize the spacing as much as he possibly can; and this is, in some cases, very troublesome. When the workman has *filled his stick*, as it is called,—that is, has set up as many lines as his stick will conveniently hold,—he lifts them out into what is termed a *galley*, by grasping them with the fingers of each hand, and thus taking them up as if they were a solid piece of metal. The facility with which some compositors can lift about what is called a *handful* of moveable type, without deranging a single letter, is very remarkable. This sort of skill can only be attained by practice; and thus one of the severest mortifications which the printer's apprentice has to endure, is to toil for an hour or two in picking up several hundred letters, and then see the fabric destroyed by his own clumsiness, leading him to mourn over his heap of broken type,—technically called *pie*,—as a child mourns over his fallen house of cards.

Letter by letter, and word by word, is the composing-stick filled; and by the same progression the galley is filled by the contents of successive sticks. In the instance of newspapers and most other periodical works, a proof is taken before the types are made up into pages. In books, however, when the compositor has set up as many lines as fill a page, he binds them tightly round with cord, and places them under his frame. We need scarcely say that the sizes of books greatly vary; but they are all reducible to a standard determined by the number of leaves into which a sheet of paper is folded. The most common size is called *octavo*, and this contains 16 pages to the sheet; the next is *duodecimo*, containing 24 pages to a sheet; and the next *octodecimo*, or eighteens, containing 36 pages in a sheet. There are many other sizes, such as the larger *quarto*, and the smaller *twenty-fours*. In every case when a sheet or sheets is complete, the compositors arrange the pages in proper order upon the imposing stone; surround each page with pieces of wood called *furniture*, so as to leave an equal margin to every page; and, finally, wedge the



A, case; B, chase; C, a form of quarto; D, galley.

whole tightly together in a stout iron frame, called a *chase.* If the work is properly executed, the pages thus wedged up, constituting one side of a sheet, termed a *form*, are perfectly tight and compact; and the *form* may be carried about with as much ease as if it were composed of solid plates, instead of being formed of 40,000, or 50,000, or even 100,000 moveable pieces.

Whether the lines which a compositor sets up are made into pages, and *imposed* as a sheet, or whether a proof is taken of them in an earlier stage, the business of the *reader* commences immediately after that of the compositor. No one unacquainted with the details of a printing-office can conceive the great differences between the correctness of one compositor and of another. The differences in the talent, the acquired knowledge, and even the moral habits of different men, are the causes of these remarkable variations. A *proof* shall be brought to the reader produced by the joint labour of two or three compositors of different degrees of merit. In a particular part of it he will find one letter constantly substituted for another, although the sense is upon the whole given correctly: this is the work of the careless and slovenly compositor, who does not take the trouble to look over the types as he sets them up line by line. He is a bad economist of his own time; for he has to correct all these faults at last, without making any charge for his correction; and he corrects them with much less ease in the second stage than in the first. Again, in another part of the proof, although the merely literal faults may be very few, there is a perpetual substitution of one word for another. This is the work of the ignorant or conceited compositor, who jumps at the meaning of his author, and thus contrives to produce the most ludicrous errors in his original proofs, and to insinuate some error or other into the most carefully corrected book. Lastly, the proof may present, and it very often does so, a most favourable specimen of what may be effected by carefulness and good sense. A wrong letter will not occur in twenty lines; a gross mistake never occurs; and, what is still more surprising, while the compositor has been engaged in an operation almost purely mechanical, he will have corrected the generally loose punctuation of the author, and produced a harmony in that most difficult department of literary labour, which is seldom attained except by long experience.

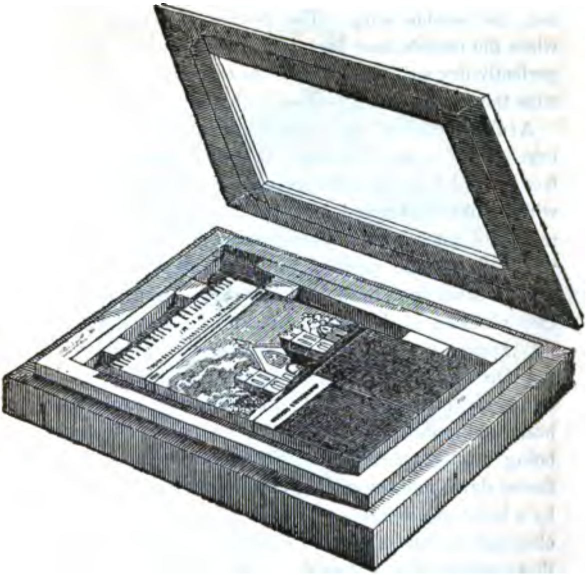
The ordinary process of correction is for the printer's reader to look upon the proof, while another person, generally a boy, reads the copy aloud. As he proceeds the reader marks, generally in the margin, all the errors which present themselves upon a first perusal. The proof then goes back to the compositor; and here a business of great labour and difficulty ensues. The omitted words and letters have to be introduced, and the incorrect words and letters have to be replaced by the correct. The introduction of two or three words will sometimes derange the order of a dozen lines; and the omission of a sentence will involve the re-arrangement of many pages. In this tedious process new blunders are oftentimes created; and these again can only be remedied by after vigilance. The first corrections being perfected, the reader has what is called a *revise*. He compares this with his first proof, and ascertains that all his corrections have been properly made. In this stage of the business the proof generally goes to the author; and it is rarely that the most practised author does not feel it necessary to make considerable alterations. The complicated process of correction is again to be gone over. The printer's reader and the author have again revises; and what they again correct is again attended to. The proof being now tolerably perfect, the labour of another reader is in most large establishments called in. It is his business to *read for press*—that is, to search for the minutest errors with a spirit of the most industrious criticism.

When the sheet is finally corrected for press, the work of the compositor is for a time at an end; but when it is printed off, or when a stereotype cast has been taken from the moveable types, it is a part of his business, and for which he is paid nothing additional, to return the types to the cases from which they were taken. This operation is called *distribution*. It is a most beautiful process in the hands of an expert compositor; and probably no act which is partly mental and partly mechanical offers a more remarkable example of the dexterity to be acquired by long practice. The workman holding a quantity of the type in his left hand as it has been arranged in lines, keeping the face towards him, takes up one or two words between the forefinger and thumb of his right hand, and drops the letters, each into its proper place, with almost inconceivable rapidity. His mind has to follow the order of the letters in the words, and to select the box into which each is to be dropped, while his fingers have to separate one letter from another, taking care that only one letter is dropped at a time. This is a complicated act; and yet a good compositor will distribute three or four times as fast as he composes,—that is, he will, if necessary, return to their proper places 60,000 letters a day. The letters, being inverted in printing, are not read as they are read in a book, and thus "to know his p's from his q's" is a difficulty to a beginner.

It is in this stage, when the pages have been rendered as correct as the care of several readers can ensure, and when the wood-cuts (if any) have been inserted in their proper places, that the process of *stereotyping* commences. This process is by no means universally applied to all printed books. Its peculiar advantages are confined to works in very large demand, and of which the demand is continued long after the first publication.

The first operation is that of taking a *mould* from each page of moveable types. It is essential that the face of the types should be perfectly clean and dry, and that no particle of dirt or other substance should attach to the bottom of the types, so as to prevent them being completely level upon the surface. The page is now placed upon the lower part of a *moulding-frame*, represented in the following cut.

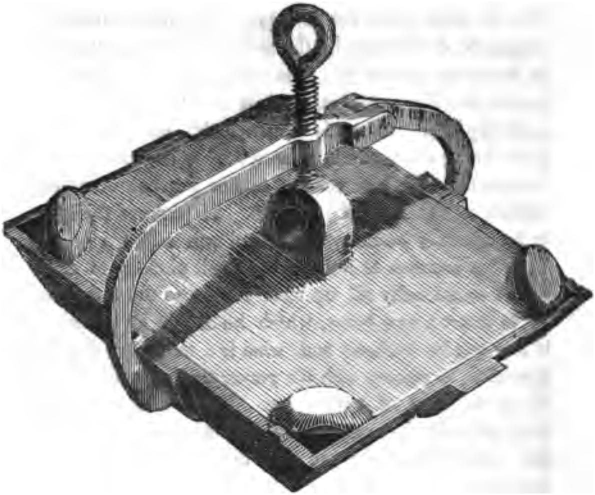
The upper part of the frame is somewhat larger than the page, and the margin of mould thus formed determines the thickness of the plate. The types having been previously rubbed over with an oily composition, gypsum (plaster of Paris) is poured evenly over the whole surface. Almost every one knows that this substance, although moulded in a liquid state, sets very quickly, and soon becomes perfectly solid. There is a good deal of nicety required from the workman, not only in forming the mould, but in removing it from the type. If any part of the plaster adheres to the face of the type, the mould is of course imperfect, and the operation must be



Moulding-Frame.

gone over again. To prevent this, considerable care is required in the preparation of the gypsum, and much neatness of hand in separating the mould from the page. Having been removed and found perfect, it requires some dressing with a knife on its edges, and several notches are cut in the margin to allow the metal to enter the mould. It is now fit for baking. This process also requires a good deal of accurate knowledge. The oven in which the moulds are placed upon their edges must be kept at a very regular temperature; for if it be too hot, the moulds warp. The process of casting begins when the moulds have been baked sufficiently long to be perfectly dry and hard. The *casting-box*, which contains the mould, is represented in the following cut.

At the bottom of the pot is a moveable plate of cast-iron, called a *floating-plate;* and upon this plate, the face of which is perfectly accurate, the mould is placed with its face downwards. Upon the back of the mould rests the cover of the casting-box, the inside face of whose lid is also perfectly true. The cover is held tightly down upon the mould by a screw, connected with two *shackles*, as shown in the above cut; and also by two *nippers*, belonging to the apparatus for plunging the pot into the metal-pit. This apparatus, which is attached to a crane, is so constructed as to swing with a perfectly horizontal motion; and the casting-pot, with the mould, being thus suspended over the metal-pit, is gradually forced down into the molten mass, and there kept steady by a lever and weight. The lid of the box, it will be observed, is cut off at the corners; and it is through these spaces that the metal enters the box, and insinuates itself into every hollow. When the box is plunged into the metal, a bubbling noise is heard, which is caused by the expulsion of the air within the box. After having remained immersed for about ten minutes, it is steadily lifted out by the crane, and swung to a cooling trough, in which the under side of the box is exposed to water. Being completely cooled, the caster proceeds to remove the mould from the casting-box. The plaster mould, the plate moulded, and the floating-plate, are all solidly fixed together. The metal, by its specific gravity, has forced itself under the floating-plate,



Casting-Box or Pot.

which it has consequently driven tightly up against the ledges of the mould. The mould has in the same way been driven tightly up against the lid of the casting-box. The notches in the ledges of the mould have, at the same time, admitted the metal into the minutest impression from the face of the types. The caster now breaks off the superfluous metal and the ledges of the mould with a wooden mallet, to separate the cast. The mould is of course destroyed; and if another plate is required, another mould must be taken from the types. After the superfluous metal and the plaster are removed, the stereotype plate comes out bright and well formed.

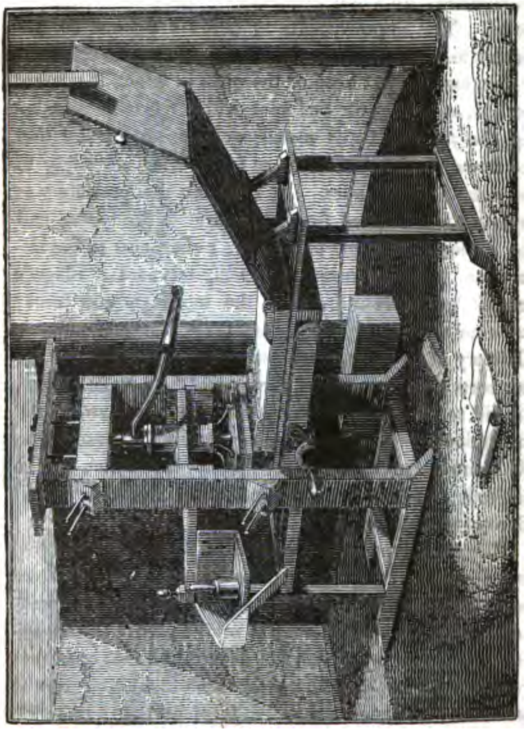
But the plate is not yet complete. Its proper thickness cannot be determined by the mould alone; and the back is therefore turned in a beautifully contrived lathe, in which the plate revolves against a cutting tool, and a perfectly true surface is obtained by the superfluous parts being cut away in a series of concentric circles. Again, the very best casting cannot prevent occasional defects in the face of the plate. It requires therefore to be minutely examined by a workman called a *picker*. It is his business to remove the small globules of metal which occasionally fill up such letters as the *a* and the *e*; to insert a new letter, which he can do by soldering, if any one be broken; and, what is a still more delicate operation, to remove with his graver any impurities which fill up the lines of a wood-cut. To execute this latter duty properly, he ought to be in some degree an artist, and possess the keen eye and the steady hand of an engraver.

It will be seen from this description, that the process of stereotyping is one which demands considerable labour, and occupies a great deal of time. In the various stages of preparing the mould, of regulating the proportions of the metal, of casting the plate, and of subsequently examining and correcting it, much skill and experience are demanded. The reader will have perceived that stereotyping is distinctly superadded to the operation of printing from moveable types. When a *form* is perfectly corrected, it is ready at once to be laid on the press or machine, without any further operation; but when a mould is to be taken from it, and a plate to be cast from that mould, the moulding and the casting involve so much additional labour and expense. Stereotyping is therefore applicable only in peculiar cases; but in those cases it is so valuable, that it may be pronounced absolutely necessary to the production of cheap books in large numbers, and therefore a most important auxiliary in the diffusion of knowledge by the printing-press.

The great and paramount advantage of the stereotype process consists in the economy of capital. The inherent difficulty of the business of a publisher consists in the mistakes he may make in calculating the demand for a particular book. The demand for food or clothing, or any other article of physical necessity, does not greatly vary. The demand for books depends, in a certain degree, upon fashion, and the prevailing current of public opinion. In books of a merely temporary interest, or which are addressed only to particular classes, and deal with particular modes of thought, a publisher often loses very considerably by over-printing. In this case the copies which remain locked up in his warehouse for years, and are at last sold for waste-paper, absorb so much capital that might have been applied to other literary purposes if the demand for them had not ceased. But in books of universal interest, which address themselves to all classes, and which consequently may be sold cheap in the expectation of a large sale, the risk of over-production is very much diminished. But the publisher must still watch the demand. He must not run too much before it with his supply, for he may be ruined by his stock;—he must not lag too much behind it with his supply, for he may thus lose the market. A small quantity of each sheet can be worked off from the stereotype plates at a day's notice; and a little foresight, therefore, can always ensure that the market shall be supplied, while the stock is kept low.

As long ago as the year 1725, William Ged, an inhabitant of Edinburgh, discovered the principle of casting metal plates. He carried the principle into commercial operation, for he was actually engaged by the University of Cambridge to print bibles and prayer-books. The compositors thought that the invention would injure their trade; and both they and the pressmen did everything in their power to lessen the credit of Ged's books, by secretly making errors in the moveable types after the pages had passed the reader. The bibles, therefore, were so defective that the University was obliged to give up the scheme. The art was revived, fifty years afterwards, by Mr. Tilloch, was subsequently prosecuted by Didot of Paris, and was ultimately brought to pretty nearly its present perfection by the late Lord Stanhope. If its progress had not been interrupted for three-quarters of a century by the ignorance of Ged's workmen, it is probable that during all that time the cost of producing bibles and prayer-books and other standard works would have been materially diminished.

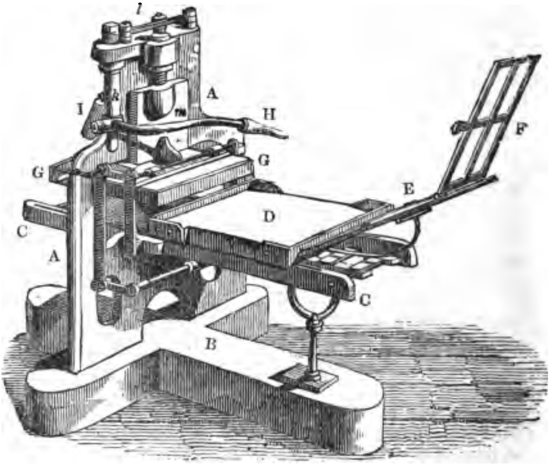
We now follow the "forms" of type, and the stereotype plates, to the printing operations. The first form of printing-press was nothing more than a common screw-press,—such as a cheese-press or a napkin-press,—with a contrivance for running the *form* of types under the screw after the *form* is inked. It is evident that this mode of obtaining an impression must have been very laborious and very slow. As the screw must have come down upon the types with a dead pull,—that is, the table upon which the types were placed was solid and unyielding,—great care must have been required to prevent the pressure being so hard as to injure the face of the letters. These defects were at last remedied by an ingenious Dutch mechanic, Willem Jansen Blaew, who carried on the busi-



The Common Printing-Press.

ness of a mathematical-instrument maker at Amsterdam; in which business he had received instruction and encouragement from the great Danish astronomer, Tycho Brahe. The improvements in Blaew's presses do not require to be particularly described. It may be sufficient to mention that the head of the press in which the screw worked, as well as the bed upon which the table containing the *form* of types rested, were yielding; and that the screw consisted of three or four worms, according to the size of the cylinder. In this way the pressure was rapidly communicated from the screw to the types; and the spring above and below gave a sharpness to the impression, while it prevented it being too hard. Blaew's presses gradually drove out the more ancient press; but even as recently as the year 1770, Luckombe, in his 'History of Printing,' then published, says, "There are two sorts of presses in use, the old and the new fashioned; the old sort till of late years were the only presses used in England." On the preceding page is a representation of Blaew's "new-fashioned" press, with which at the beginning of the present century all the printing of Europe was performed.

The stereotype improvements of Lord Stanhope, just described, and the printing-press invented by that nobleman, which bears his name, offered the first great practical improvements in the art of printing, with the exception of Blaew's press, that had been called into operation during a period of 350 years. The Stanhope press is as superior to Blaew's wooden press as that was to the rude press that preceded it. Being composed entirely of iron, the surfaces brought into contact when the impression is given are perfectly level: and the combination of levers which give motion to the screw diminish the labour of the workman, while they add to its efficiency. This invention undoubtedly enabled printing of a better average quality to be produced; but it added very slightly to the speed with which impressions could be thrown



The Stanhope Press.

[A, the frame ; B, the support ; C, the table ; D, the form of types ; E, the tympan ; F, the frisket ; G, the plattin ; I, the counterweight ; H, the handle ; *k*, *l*, *m*, pressure mechanism.]

off. Both at the Stanhope press and at the wooden press the same general rate of work was maintained, namely, 250 impressions on one side of a sheet per hour, to be produced by the joint labours of two men, one inking the types, the other laying on the sheet and giving the pressure.

The mode in which the ink was applied to the types remained quite unchanged for three centuries and a half. Inking-cushions, technically called *balls*, were universally used. As the ancient weaver was expected to make his own loom, so, even within these few years, the division of labour was so imperfectly applied to printing that the pressman was expected to make his own ink-balls. A very rude and nasty process this was. The sheepskins, called pelts, were prepared in the printing-office, where the wool with which they were stuffed was also carded; and these balls, thus manufactured by a man whose general work was entirely of a different nature, required the expenditure of at least half an hour's labour every day in a very disagreeable operation, by which they were kept soft. The quantity of ink wasted by these balls was enormous; but they have now been superseded, and their waste of material and time got rid of, by an invention applicable not only to printing by machinery, but printing by hand.

Such was the state of the press department of printing, not only in England, but throughout the world, till the year 1814. As several approaches had been made before the time of Faust to the principle of printing books from moveable types, so the principle of producing impressions from a cylinder, and of inking the types by a roller, which are the great principles of the printing-machine, had been discovered in this country as early as the year 1790. In that year Mr. William Nicholson took out a patent for certain improvements in printing, the specification of which clearly shows that to him belongs the first suggestion of printing from cylinders. But this inventor, like many other ingenious men, was led astray by a part of his project, which was highly difficult, if not impracticable, to the neglect of that portion of his plan which, since his time, has been brought into the most perfect operation. Nicholson's patent was never acted upon. The first maker of a printing-machine was Mr. Koenig, a native of Saxony; and the first sheet of paper printed by cylinders, and by steam, was the 'Times' newspaper of the 28th November, 1814. The machine thus for the first time brought into action, was that of Mr. Koenig.

Before we proceed to a description of the printing-machine, let us imagine a state of things in which the demand for works of large numbers should have gone on increasing, while the mechanical means of supplying that demand had remained stationary—had remained as they were at the beginning of the present century. Before the invention of stereotyping it was necessary to print off considerable impressions of the few books in general demand, such as bibles and prayer-books, that the cost of composition might be so far divided as to allow the book to be sold cheap: with several school-books, also, it was not uncommon to go to press with an edition of 10,000 copies. Two men working eight hours a-day each, would produce 1000 perfect impressions (impressions on each side) of a sheet per day; and thus if a book consisted of twenty sheets (the size of an ordinary school-book), one press would produce the twenty sheets in 200 days. If a printer, therefore, were engaged in the production of such a school-book, who could only devote one press to the operation, it would require very nearly three-quarters of a year to complete 10,000 copies of that work. It is thus evident, that if the work were to be published on a given day, it must begin to be printed at least three-quarters of a year before it could be published; and that there must be a considerable outlay of capital in paper and in printing for a long time before any return could be expected.

But take a case which would allow no time for this long preparation. Take a daily newspaper, for instance, of which great part of the news must be collected and written and printed within twenty-four hours. Before the application of machinery to the printing of newspapers, in 1814, there were nearly as many daily London newspapers as at present; but their average size was much smaller than those now published. The number of each paper printed was less than at present; and the later news was much more incompletely given. The mechanical difficulties of printing a large number within a limited time required to be overcome by arrangements which involved considerable expense; and thus less capital was left to be expended upon that branch of the outlay by which the excellence of a newspaper is mainly determined,—namely, the novelty, the completeness, and the accuracy of its intelligence. Let us take, for example, the 'Times' newspaper for some years prior to 1814, when it began to be printed by machinery. When that paper was originally established, somewhere about forty years ago, the present system of reporting speeches in parliament on the same night that they were spoken was scarely ever attempted. A few lines mentioning the subject of the debate, and the names of the principal speakers, were sometimes given; but anything like a sketch of the general debate, or a report of any remarkable speech, was deferred to a future day, if it were published at all. Mr. Woodfall afterwards introduced an improved system of reporting; but the sale of the newspapers must have been necessarily limited by the mechanical difficulties of their production. A newspaper, being made up of many distinct articles, does not require, as a book does, that the whole of the types of which it is composed should be set up before one side of it is printed off. The outer side of a daily paper, which ordinarily consists of advertisements, communications, and paragraphs of minor importance, may be printed off some hours before the inner side, which contains the later news, is ready to be printed. Such an arrangement of course would prevent the whole paper being filled with the latest news, as is now frequently the case; and thus all the papers printed before the invention of the machine will be found to be constructed with reference to this principle of having one half printed long before the other half was ready to be printed. But let us see how that half, which contained the last intelligence, was brought out previously to 1814. If we refer to such a paper containing a report of any great parliamentary debate, we shall find the speeches generally given of a length not proportioned to their importance, but to the time of the evening in which they were delivered. Those reporters to whose share the earliest speeches fell gave them fully, because there was time for printing them; and this fullness left little space for the more important speeches which at that period generally closed the debate. The quality of reporting was therefore injured by the brevity required for all speeches delivered after midnight. Without this sacrifice the paper could not have been published at all on the day whose date it bore; and even with this sacrifice the difficulty of meeting the demand was excessive. The only mode in which it could be met was by setting up a portion of the paper in *duplicate*,—that is, setting up two sets of types, *so that* two presses might be engaged in printing it off *at the* same time. Sometimes in large papers, such as *the* 'Times,' a page only was worked at one press, *to* enable the pressman to proceed with great speed. If the House of Commons now sits to four o'clock, and the 'Times,' or the 'Chronicle,' or the 'Herald,' cannot be ready for printing off till six o'clock at the earliest, the papers are nevertheless published, so that the country and the *town* may by supplied without intermission. In such a case, before the introduction of the printing-machine, the morning coaches would have departed without a paper, and the people of London would have received them at the hour of dinner instead of that of breakfast. The printing-press, as we have mentioned, will, at the ordinary rate, enable two men to take off two hundred and fifty impressions in an hour. By the most violent exertions the pressmen of a daily newspaper were enabled, with relays, to work off about five hundred copies in an hour. One press would therefore produce ten thousand copies in about twenty hours. It is manifest that such a rate of speed, if such a quantity were demanded, would be incompatible with the production of a daily paper, the condition of whose existence is that it must be wholly printed and issued in four and twenty hours. Let us double the speed by printing in duplicate; and we find that ten thousand copies can be produced in about ten hours. But even this rate carries the publication of several thousands of the ten thousand printed into the next afternoon.

When we compare these results with those produced by the printing-machine, which can print four or five thousand copies in an hour, we gain some insight into the value of the change.

The power which sets the modern printing-machine in action is supplied by steam-engines. Upon entering the machine-room of one of the larger printing-offices, a stranger feels a little bewildered by the din of so many wheels and cylinders in action. One man, and sometimes two men, are engaged in what is technically called *making ready*; and this with stereotype plates is a tedious and delicate operation. The plates are secured upon wooden blocks, by which they are raised to the height of moveable types; but then, with every care in casting, and in the subsequent turning operation, these plates, unlike moveable types, do not present a perfectly plane surface. There are hollow parts which must be brought up by careful adjustment; and this is effected by placing pieces of thin paper under any point where the impression is faint. This process often occupies six or seven hours, particularly where they are cast from wood-cuts. Let us suppose it completed. Upon the solid steel table at each end of the machine lie the pages which print one side of the sheet. At the top of the machine, where the laying-on boy stands, is a heap of wet paper. The paper undergoes the process of wetting previously to entering the machine-room. Each quire of paper is dipped two or three times, according to its thickness, in a trough of water; and being opened is subjected first to moderate pressure, and afterwards to the action of a powerful press, till the moisture is equally diffused through the whole heap. If the paper were not wetted, the ink, which is a composition of oil and lamp-black, would lie upon the surface and smear.

To return to the machine. The signal being given by the director of the work, the laying-on boy turns a small handle, and the moving power of the strap connected with the engine is immediately communicated. Some ten or twenty spoiled sheets are first passed over the types to remove any dirt or moisture. If the director is satisfied, the boy begins to lay on the white paper. He places the sheet upon a flat table before him, with its edge ready to be seized by the apparatus for conveying it upon the drum. At the first movement of the great wheel, the inking apparatus at each end has been set it motion. The steel cylinder attached to the reservoir of ink has begun slowly to move,—the 'doctor' has risen to touch that cylinder for an instant, and thus receive a supply of ink,—the inking-table has passed under the 'doctor' and carried off that supply,—and the distributing-rollers have spread it equally over the surface of the table. This surface having passed under the inking rollers, communicates the supply to them; and they in turn impart it to the 'form' which is to be printed. All these beautiful operations are accomplished in the sixteenth part of a minute, by the travelling backward and forward of the carriage or table upon which the 'form' rests. Each roller revolves upon an axis which is fixed. At the moment when the 'form' at the back of the machine is passing under the inking-roller, the sheet, which the boy has carefully laid upon the table

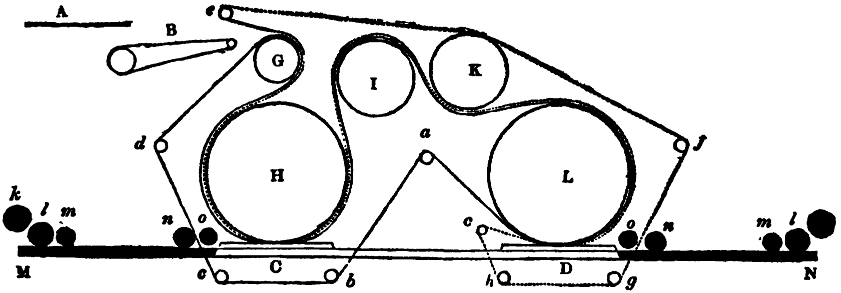
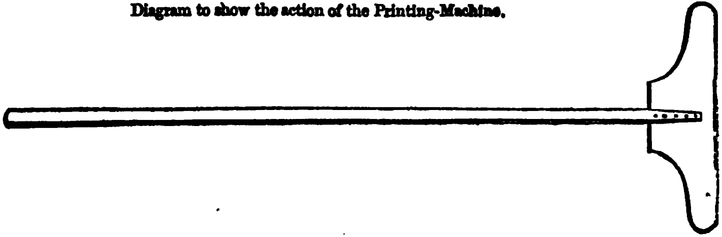
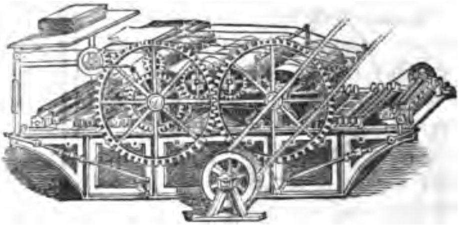


Diagram to show the action of the Printing-Machine.



A Printer's Peel.

before him, is caught in the web-roller and conveyed to the endless bands or tapes which pass it over the first impression cylinder. It is here seized tightly by the bands, which fall between the pages and on the outer margin. The moment after the sheet is seized upon the first cylinder, the 'form' passes under that cylinder, and the paper being brought in contact with it receives an impression on one side. To give the impression on the other side the sheet is to be turned over; and this is effected by the two drums in the centre of the machine. The endless tapes never lose their grasp of the sheet, although they allow it to be reversed. While the impression has been given by the first cylinder, the second 'form' of types at the other end of the table has been inked. The drums have conveyed the sheet during this inking upon the second cylinder; it is brought in contact with the types; and the operation is complete.

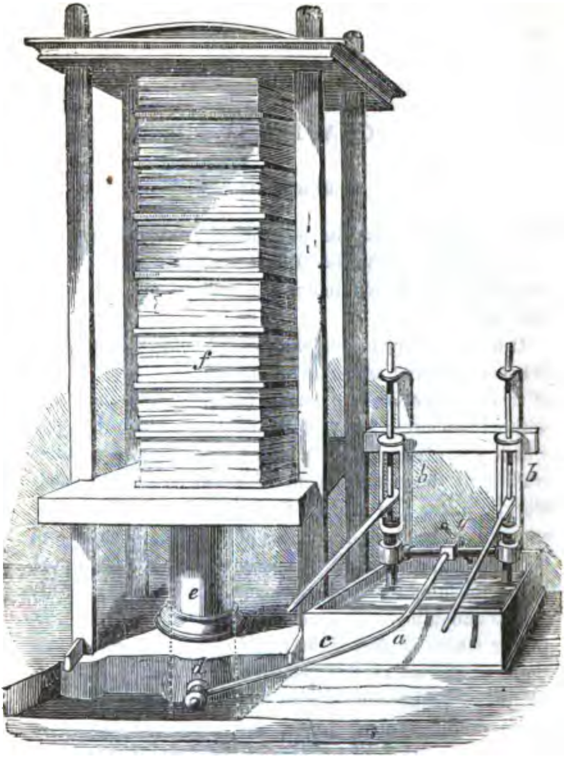


Printing-Machine.

The above details may be illustrated by the diagram on the preceding page, thus:—The sheet of paper taken from the table A is laid on the feeder B, which consists of girths of linen, tightly stretched by being passed round two cylinders. By the motion of this feeder the sheet is placed between the two systems of tapes which lie on the cylinder G: these tapes, of which one set is represented by the dotted line, and the other by the thin line, lie two and two over each other on the cylinders and small rollers *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*. The sheet of paper grasped between them is kept clean at the places in which it is in contact with them, and by the motion of the various parts is conducted under the first printing-cylinder H, and receives an impression from the types at C; thence by means of the cylinders I, K, to the second printing-cylinder L, where it receives an impression on the other side from the types at D. Thus printed on both sides, it is taken out at *e* by the attendant. The cylinders I and K are simply for purpose of conveying the sheet steadily and smoothly from one printing-cylinder to the other. The sheet will be seen to be reversed in its progress from one set of types to the other, descending the left side of the first and the right side of the second printing-cylinder. An inking-apparatus is placed at each end of the table M, N, which carries the types C, D, and which traverses backwards and forwards under the printing-cylinders L, H, and inking-rollers. The ink, received from a reservoir *k* by the two rollers *l* and *m*, is transferred from them to the surface of the table; the surface of the table inks the rollers *n*, *o*, and these, in their turn, ink the types as they pass backwards and forwards for each impression.

The machine thus described is a most important improvement of Koenig's original invention. That, like most first attempts, was extremely complicated. It possessed sixty wheels. Applegath and Cowper's machine has sixteen only. The inking apparatus of this machine is by far more complete and economical than any other before invented. Nothing can be more perfect than the distribution of the ink and its application to the types. It has therefore entirely superseded Koenig's machine; and as the patent has expired, its use is rapidly extending, not only in England, but throughout Europe.

When a newspaper is printed off, it is at once removed from the machine or the press to the publisher's counter, and then sold wet to the distributors. It is important that the sheets for a book should be delivered dry. A printer's warehouse, from which books are issued in large quantities, is a scene of great activity. The drying process is now a tolerably rapid one, by the conveyance of steam or hot air through the drying-rooms. The sheets are here hung upon poles, by means of an instrument called a 'peel,' and in a few hours acquire the necessary hardness. They are next counted into quires; and if time permits, the quires are made perfectly smooth and compact by heavy pressure. The hydraulic press, a singularly powerful and useful piece of machinery, is now very generally employed for this purpose.



Hydraulic Press.

[Water is forced by the pump *b*, from the cistern *a*, through the pipe *c*, to *d*; where it forces up the piston *e*, and compresses the pile of printed sheets *f*.]

## CHAPTER IV.

### BOOKBINDING.

HAVING thus traced the mechanical processes involved in the printing of the sheets for a book, we shall in this chapter notice the binding of those sheets into the book-like form.

It is a necessary consequence of the connexion existing between different branches of manufacture, that no one of them can receive any notable increase or advancement without benefiting many of the others. Thus, the spur which was given ten or a dozen years ago to popular reading by the establishment of works issued at a small weekly price, and many of them illustrated by wood-engravings, has been the means of inducing changes and eliciting improvements in nearly all the arts connected with publishing :—wood-engraving, paper-making, printing, bookbinding—all have been affected by a moving-power which at first sight might appear a trivial one. Some of the works now published at a penny or three-halfpence weekly can vie with the costly works of bygone years in illustrations, paper, and printing; and those persons who were schoolboys in the days when schoolboys were whipped through 'Vyse's New London Spelling-book,' will not fail to see how rapidly such books are assuming the neat gilt-lettered cloth covers of modern times in place of the nankeen 'roan' of past years.

In the large establishments where bookbinding is carried on for the publishers, the store-rooms and workshops are very numerous. Thus, one room is the 'board-warehouse,' where the millboard, purchased from the stationer in sheets of various sizes and thickness, is deposited in classified recesses till wanted. Another is the 'cloth-warehouse,' where the cotton-cloth, now so extensively used for covering books, is kept and cut to sizes. A third is the 'embossing warehouse,' filled with pieces of leather or cloth which have received some of those ornamental devices to be described hereafter. One room contains machines for imparting to cloth the diamond or granulated or speckled appearance usually presented by books in cloth boards; an appearance which nearly hides the rectangular interlacings of the warp and weft threads. The 'embossing shops' contain powerful machines for giving to the flat covers of books those beautiful devices which now so often distinguish them: if the book be a Bible, we have an emblematical device of a religious character; if it be a 'Shakspere,' we have something pertaining to the great dramatist; if it be a lady's album or portfolio, or letter-case or blotting-book, we have a device of a graceful and ornamental character. This is an approach towards what may perhaps be termed a 'principle' in bookbinding, viz., that the subject of a book may be known from its cover; a principle which seems to have much to recommend it.

Then there is generally a 'boarding-shop,' wherein all the operations are conducted for binding books in cloth boards, the most prevalent style at the present day. Here females are engaged in folding the sheets, gathering them into groups, sewing them into the form of a book, &c.; while men are pursuing the subsequent operations of glueing, pasting, cutting, hammering, pressing, &c., by which the book is brought to a finished state. In many branches of manufacture it is found convenient to locate the workmen according to the kind of labour required; but in bookbinding on a large scale it is found desirable to classify with respect rather to the style in which the book is to be bound, than to the nature of each individual process. All the other departments are, in the larger establishments, similarly classified and grouped. In describing the book-binding processes, we shall classify the various operations in three groups, according as they relate—1st, to *making-up* a book; 2nd, to *covering* a book; and 3rd, to *decorating* a book. A bookbinder would probably object to this mode of classification; but we think it will meet the wants of the reader better than a more technical mode of arrangement.

1st. *Making-up a book*. It must be obvious to all who reflect that a book is printed in large sheets, *that* these sheets must be separately folded and then connected together, before they can assume the form of a book. If we open, without cutting, a number of any periodical which consists of four leaves, we see that the eight printed pages are so arranged, as to follow in proper order when the sheet is folded in a certain manner; and if, as in a large number of other works now issued periodically, there are sixteen pages in a number, the arrangement of these pages appears singularly confused when the opened sheet is inspected; but here, as in the former case, the pages are arranged solely with reference to the order of sequence when folded. Each sheet has at the bottom of the first page a letter, figure, or other symbol, called a 'signature,' intended to assist in arranging sheets properly in the volume.

The printer sends the sheets to the binder (we are speaking of bookbinding on a large scale) in large heaps or groups, arranged in one of two forms; either many copies of one sheet, or ten or twelve successive sheets of one volume, form the group; in the latter case the heap is called a *gathering*, or *quire;* but we will suppose the former to be the case, as it will enable us to speak of the gatherers. The heap of sheets passes to the hands of the *folders*, who are almost invariably females. Each folder sits before a flat table or bench, on which she spreads out the sheets in succession. In her right hand she holds a small ivory or bone folding-knife with which she flattens the foldings of the sheet. Every successive sheet of the group is folded in precisely the same way as that which preceded it, so that no particular skill is required in adapting the various sheets one to another; but the folding is nevertheless a process requiring much accuracy, especially in the finer kinds of binding, as the sheet is folded so as to make the top and bottom lines of the print range, without reference to the edge of the paper. The sheet is placed with the signature towards the left hand of the folder, on the under surface; and the foldings are more or less numerous according as the book is folio, quarto, octavo, 12mo., 16mo., 18mo., 24mo., 32mo., &c., terms which relate to the number of printed pages in one sheet.

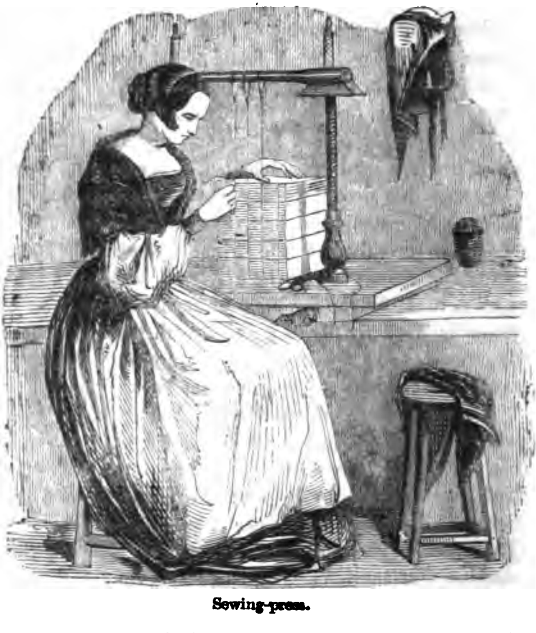
Supposing a group of signature A to be thus folded, another of signature B, and others, to the extent required for the volume, these will have to be 'gathered' into volumes at the next process. This gathering is simply breaking up the groups hitherto existing, and re-arranging the same sheets in the order necessary for the volume. Instead, for instance, of having twenty copies of one sheet, such as that with the signature A, one of A is taken, and then one of B, then one of C, and so on, until there are as many groups as volumes, and each group containing the sheets for one volume. This 'gathering' is in most cases done by the printer before the sheets pass into the hands of the bookbinder.

The 'collater' now takes the group of sheets in hand and examines them to see that they occur in proper order, that no duplicates occur, that no sheet is wanting, that the folding is correct, &c. This is a process in which much expertness is shown. The group is bent at one corner, and the sheets allowed to spring back successively, leaving to the eye just sufficient time to catch the signature at the bottom of the first page of each. If these signatures occur regularly, according to the letters A, B, C, &c., or the figures 1, 2, 3, &c., or any prescribed combination of both, then the arrangement is correct; if not, any error is immediately adjusted.

When the book of loose sheets has been thus made up, the sheets are either at once sewed, or are previously beaten or pressed, according as the work is to be 'in boards' or 'bound.' It is well known that a bound book is more dense and compact than one in boards, and this difference is mainly due to the process immediately preceding the sewing. Until recent times the sheets were separated into small groups, called 'sections' or 'beatings,' and beaten with a heavy hammer till greatly compressed; but modern invention has marked out a much more effective mode of proceeding. The *rolling-press* is a machine in which two rollers, worked by hand, are made to rotate nearly in contact; a man places a small number of folded sheets between two tin plates, and passes them between the rollers, on the other side of which they are received by a boy, who places the pressed sheets in heaps, and returns the tin plates to the man. Independent of the saving of time and of muscular exertion, the rolling-press is found to be more efficacious than the hammer in producing less 'set-off,' or transference of ink from one page to another.

The sheets are placed for a short time in a standing-press, and are then again *collated*, to see that no disarrangement has occurred; any plates, too, which may be interspersed among the text, are now inserted. The *sewer* now sews the sheets to strings or bands at the back; but if the strings are to be rendered invisible, a *saw-mark* is made for the reception of each. The group of sheets is fixed tightly in a press, with the back edges uppermost, and a few shallow cuts are made with a saw, at right angles with the length of the book.

A *sewing-press* consists of a flat bed or board, from which rise two end-bars, connected at the top by a cross-bar. Three or more strings, according to the size of the book, are fastened by loops to the cross-bar, and are tightened down by a simple contrivance at the lower end. The sewer, seated somewhat obliquely in front of this machine, with her left arm passing round the left vertical bar (as seen in the annexed cut), proceeds to sew the various sheets to the bands, her left hand being behind the strings, and her right hand before. Each successive sheet is laid flat on the bed of the sewing-press, with the back edge in contact with the strings, then opened in the middle, and fastened to the strings, by passing a threaded needle backwards and forwards through the central fold of the sheet; each thread, after passing from the inside to the out, being made to loop or twist round one of the strings before entering the sheet again. As soon as one sheet is fastened to all the strings, another is laid down on it, and fastened in a similar manner. A curious kind of stitch, called a 'kettle-stitch,' is made near the top and bottom of the book, as a means of al-



Sewing-press.

lowing the thread to pass on from one sheet to another. Nonprofessional readers may be sorely puzzled to know what 'kettle-stitch' means; but we can only say that it is supposed by some to be a corruption of 'catch' or 'ketch' stitch, while others refer it to 'chain' stitch. Those who would attempt to trace the etymology of technical terms and phrases would soon find themselves in a sea of mystery both wide and deep.

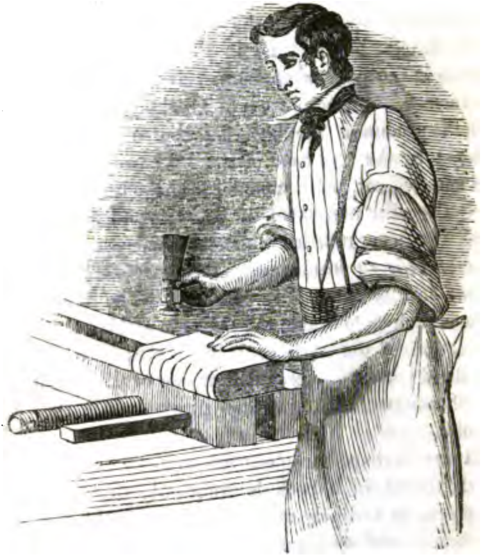
The operation of sewing is conducted with great rapidity, since a female can sew two or three thousand sheets a day. Many modifications of the process occur, according to the size of the book and the style of binding. Thus, the number of strings may be only three, or may amount to eight or ten; or instead of strings, strips of vellum or of parchment are sometimes used. In some cases the needle passes through eight thicknesses of paper, in others six, in others four, in others two; according to the size of the sheet, the number of pages in it, and the mode in which the pages are arranged. It is a fortunate circumstance, considering the very limited number of employments for females in this country, that there are several departments of bookbinding within the scope of their ability. The greater part of that which has hitherto engaged our attention is intrusted to females; and in a large bookbinding establishment employment is thus afforded to a considerable number.

While speaking of making-up a book, we must remark that caoutchouc or India-rubber binding requires no sewing. The sheet is cut into separate leaves, and these leaves are retained solely by a cement of caoutchouc applied to their hinder edges. The leaves are allowed to assume a round contour at the back edge by placing them in a kind of mould or gauge shaped for the purpose; they are then rasped, to give a slight roughness for retaining the caoutchouc afterwards applied. A flexibility is produced by this kind of binding, greater than can be presented by a sewed book; while at the same time the caoutchouc cement is so retentive as to bind every single leaf firmly. This new mode of binding was introduced a few years ago, and is valuable for many kinds of volumes.

2nd. *Covering a Book.* We have now made up the sheets into the form of a book, and have connected them together. Whether the volume is in elegant 'calf-extra,' or 'Russia-extra,' or whether it is a roan-bound school-book, or a 'boarded' book, the sheets are brought together in some such mode as we have attempted to describe above. Here then we shall commence the second of the three sections into which we have thought it proper to classify the operations. The 'cover' of a book, in bookbinders' phraseology, is the piece of leather or of cloth which envelopes the millboard; but the reader of a book, when he speaks of its cover, gives the term a much more extensive application. We must therefore at once explain that the leather or cloth is called the *cover*, the stiffening substance within is the *board*, and both taken collectively the *case*.

When the book is taken from the sewing-press, an inch or two of each string is left hanging to it; these are afterwards either scraped so thin as to be but little conspicuous, or are employed for fastening the book to its case. The back of the book—that is, the assembled back-edges of all the sheets—is glued, to increase the bond by which they are held together. When the book has gone through one or two other minor processes, that one succeeds which is perhaps as remarkable as anything displayed in bookbinding; viz. rounding the back and hollowing the front. Most persons can understand the production of a square back and edge to a book; but the graceful convexity of the one and concavity of the other, in most books bound in the modern style, are as curious in the mode of production as they are pleasing in appearance. In the process of 'backing,' by which this effect is produced, the book is laid on a bench, held or pressed by the left hand of the workman, as shown in the annexed cut, and hammered near the back edge, with such a peculiar movement of the left hand as causes the back to become rounded while the hammering proceeds. The effect is so instantaneous that a looker-on scarcely knows how or when it is produced. The state of the back is such as to enable the sheets to yield to the rounding action of the hammer, being coated with glue not yet dried; and the subsequent drying of the glue retains the sheets permanently in the position which they thus acquire.

It may perhaps have occurred to many a reader, that, as the board of a book is frequently of considerable thickness, it is likely to project beyond the back and to form a stiff and inconvenient hinge. This is prevented by a very simple contrivance, adopted at the time when the book is 'backed.' It is placed between two pieces of plank called 'backing-boards,' the hinder edges of which are placed precisely where the two hinges of the book are to come. The book with the boards thus placed, is then squeezed tightly in a press, with the back edge uppermost; and the back being thus again hammered into a round form, a portion of edge projects over the boards, so as to form a kind of groove into which the millboard may afterwards conveniently be adjusted.



Rounding the Back of a Book.

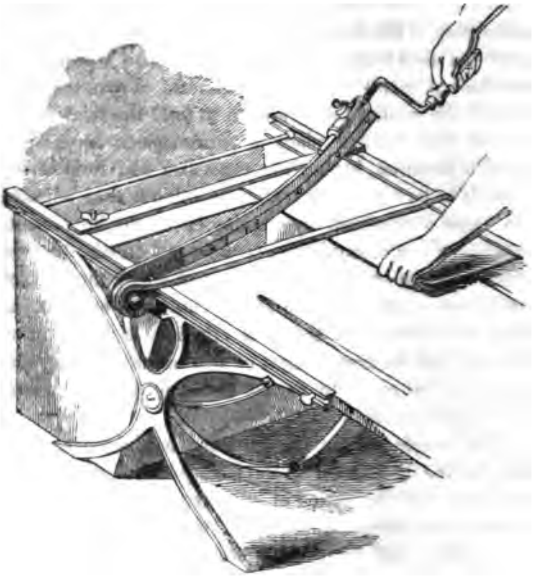
The reader will bear in mind that the edges of the book are all this time rough and uneven; but the time has now come when these edges must be brought to the level and smooth surface which adds so much to the beauty of a book. There are a few minor processes carried on about this time; but it will only be necessary that we should notice those of most prominent importance or use. In former times the edges were cut in a most clumsy and rude manner by means of shears, one blade being fixed to a bench, and the other being moved by the right hand of the workman, while his left hand held the book, and thus the leaves were cut a few at a time. The cutting of the edges was partly effected by this method, and partly by drawing the edge of a sharp knife along the leaves, guided by the edge of a board. The 'cutting-press' of the present day is however a much more effective arrangement. The book, after being properly adjusted between two boards, is screwed in a press, with one of the ends projecting a little above the level of the bench. The ends of all the leaves are then cut off while in this position, by means of an instrument called 'a plough,' the cutting edge of which in its mode of action is midway between that of a pointed knife and a plane-iron. The edges are all cut to a perfect level; and the book being reversed, the other end is similarly treated. But by far the most remarkable part of the process is that by which the concave front edge is brought to such a regular curve. Most persons who have thought of the matter at all may have conceived that this concavity is produced by scooping out a portion with a gouge; and indeed the circumstance of the concavity of the front edge being just the same in degree as the convexity of the back has given rise to many sage conjectures wholly wide of the truth. The glue with which the back of the book had previously been coated is so far softened as to suffer the bands and the back edges of the sheets to yield to pressure; and this is followed by an operation which makes a stranger fear that the round of the back is destroyed for ever. The workman takes the book in his hand, front edge uppermost, and strikes the back forcibly against the bench; thus transforming the round back into a square back. Then, using some contrivances to keep the sheets in this position, he fixes the book in the cutting-press, and cuts the front edge in precisely the same way as the top and bottom; thus making all the edges perfectly square, and all the leaves perfectly equal in size. The most remarkable part of the operation then succeeds; for immediately on removing the temporary fastenings from the book, the whole of the leaves spring back to their former position, that is, convex at the back edge; and the slightest consideration of the nature of curvature will make it manifest that, as all the leaves are made perfectly equal in the cutting-press, a convexity at one edge must be accompanied by an equal concavity at the other. Hence is produced the hollow or 'gutter' of the front edge.

In this, as in other parts of bookbinding, the process is modified to suit different circumstances. Books in boards are either not cut at all at the edges, or are only partially cut; while bound books are carefully cut at top, bottom, and front edges.

We next turn our attention to the boards, which are permanently attached to the book in different stages of its progress towards completion, according to the nature of the binding. Millboard, the stiff substance of which the sides of books are formed, is a thick pasteboard composed of many parallel layers, glued or pasted together, and pressed in a mill to make them dense and smooth. The sheets are of various sizes and thicknesses, according to the size of book for which they are required; and the bookbinder sometimes glues two together, to produce a board of double thickness. From the large sheets the smaller pieces are cut to form the sides of the books. In the first place, a pattern-piece or size-pattern is prepared, having the exact size and form of the boards to be cut. The cutting-machine is then adjusted to these dimensions, by causing an edged instrument, analogous to a scissor-blade, to work at a certain distance from a groove or raised ledge, against which the edge of the board is placed. The actual cutting is effected, as here represented, on the same principle as by a pair of shears; but the arrangement of the machine enables the pieces to be cut with perfect accuracy, both as to size and to rectangular form.

The boards are cut by the same machine, whatever may be the department of the factory where they are to be used; but the period of adjusting them to the book depends on circumstances which we may now explain. If a book is put into 'cloth boards,' or is 'bound in cloth,' the cloth cover is attached to the boards before the latter are attached to the book; but if the book is 'bound' or 'half-bound' in leather, the boards are first attached to the book by means of the strings, and the leather cover is pasted on afterwards. In the one instance the cloth is cut from the roll to the required size in the cloth-warehouse, and handed over to the 'cloth-case maker;' in the other, the leather is cut from the skins in the leather-warehouse, and consigned either to the binders or to the embossers.

A boarded book is attached to its covers almost entirely



Board-cutting Machine.

by the boards being pasted to the blank-leaves, or 'end-papers,' placed by the binder at the beginning and end of the book. The 'cloth case' is first prepared by pasting the cloth upon the boards, placed sufficiently wide apart to allow for the thickness of the book; and the case, thus made, is attached to the book by the back of the book being covered with stout linen and afterwards fastened to the case; the end-papers are then glued to the boards.

In a bound book, however, the process is different, and more carefully conducted. The boards being adjusted to the proper sizes, the back of the book rounded, the edges cut, holes made through the boards opposite to the strings, and the strings of the proper length, the boards are fastened to the book by passing the ends of the strings through the holes and pasting them down. The 'hollowness' in the backs of some books depends on a cause independent of the fastening of the bands or strings. If we open a 'hollow-backed' book we shall see that the leather or cloth cover springs away from the back edge of the sheets; whereas other books appear to have the leather firmly attached thereto. This difference arises simply from the interposition of a doubled layer of paper or cloth between the leather and the back of the sheets: this layer helps to strengthen the book, and, at the same time, admits of the back being made close or hollow, according as the two layers of paper are or are not made to adhere together. If we suppose a hollow cylinder of paper to be pressed flat, and one side pasted to the back edge of the sheets, while the leather cover is pasted to the other side, we shall have some idea of the nature of a 'hollow back.'

When a book, attached to its boards by means of the bands, is ready to receive the leather covering, the leather is cut to the required size, allowing about half an inch all round for paring and turning in. The edge is pared or cut away obliquely with a keen knife, to prevent the unseemly projection which would otherwise result. If it is to receive any of those decorations which add so much to the external beauty of a book, the imprinting of the devices is done partly before and partly after the leather is attached to the book, as we shall explain further on. But the mode of pasting the cover on the book is the same in both cases. The leather is laid smooth with the face downwards, and the back surface well coated with paste. The workman then takes the book in his hands, lays the back evenly in the middle of the leather, and draws and smooths and works the latter until it adheres closely to the back and boards of the book. This is a process of very great nicety; for not only must the more obvious parts of the surface be closely covered, but the overlapping edges, the turning-in, the corners, &c., must all be finished with great exactness, or the book will be at once spoiled. It is one of those operations, so frequent in manufactures, wherein success depends on a nicety of manipulation, as incapable of being described as of being imitated without long practice.

There is one little appendage which we may notice here, viz. the *head-band*. Every one is familiar with the fact that his Bible has a little band or edging of silk at the top edge, where the paper joins the covers. This head-band is partly for service and partly for appearance; it helps to sustain the leather at the back of the book at the same level as the boards; and it gives a neat finish where slight imperfections might be otherwise visible. The better kinds of head-bands are formed of little strips of vellum or pasteboard, with coloured silk twisted over and around them in the process of fixing them to the book; while the commoner kinds consist of a cord inserted in a doubled piece of coloured silk or cotton-cloth. We may also here mention the 'raised bands' which are sometimes used for ornament in the better kinds of books; they consist of little strips of leather or cord pasted across the back of the book before it is covered, and afterwards stamped and gilt so as to contribute to the beauty of the volume.

3rd. *Decorating a Book.*—We have glanced through the more prominent operations by which the book is made to assume its compact, convenient, and durable form; omitting mention of many slighter manipulations which would neither suit our limits nor be intelligible to general readers. There is, however, a wide difference between a book thus prepared and as given in a finished state from the hands of the bookbinder. The edges of the leaves are cut; but they are white, neither coloured nor gilt: the boards are covered with cloth or with leather; but neither cloth nor leather is embossed or stamped, or gilt or lettered. As these adornments are subsidiary to the formation of the book itself, we have thought it better to group them by themselves, whether they are done before or after the cover is laid on the book.

First, then, for the edges. The majority of cut-edged books are treated in one of two ways—*sprinkled* or *gilt*; the first being the most general method for bound books; and the second for Bibles, Prayer-books, Annuals, and the higher class of bound books. The sprinkling is a singular process, and one which differs greatly from the idea which many may have formed of the matter. The edges of the majority of bound books present a speckled appearance, arising from a coloured liquid or paint being laid irregularly over them; and the peculiarity consists in the mode of producing the small spots. The colour is laid on, not with a brush, as in painting, but by the following contrivance:—A set of books, to be sprinkled of one colour, are ranged side by side on a bench, in a recess shielded from other parts of the factory. A colour is mixed up, of umber, Venetian red, or any other cheap pigment, with water and paste or size; into this the workman dips a large brush, and then strikes the handle or root of the brush against a stick held in the other hand at a height of two or three feet above the books: the action is so governed as to cause a shower of spots to fall on the edges of the books; which spots are not so thickly congregated as to cover the whole surface, and are yet such as to have an equable appearance when finished. The mode of handling the brush is obviously the point on which the success of the process hinges. Some books have the edges *marbled*, instead of *sprinkled*; this is done in a manner similar to that observed in making *marbled paper*, and is the work of a separate class of men.

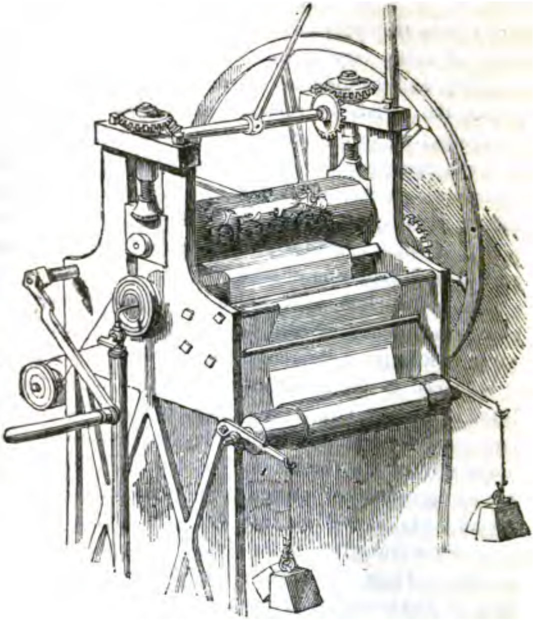
The operation of gilding the edges of the books is one which illustrates in a striking manner the dense and compact form into which the leaves of a book are brought by pressing and binding. The edge of a well-bound Bible presents a fine, smooth, glossy, and brilliant surface, so equable and uniform as to render the distinct leaves almost invisible; yet these leaves can be parted as easily as if their edges were not gilt, and each edge presents its fine and delicately-marked line of gold. Were not the leaves pressed together as compactly as a mass of wood, this effect could not be produced.

There is in the process of gilding edges, as well as that of cutting them, a necessity that the front and back of the book should be brought perfectly square before the operation. The leaf-gold could not be bent into the curvature of the 'gutter' if this were not temporarily made flat: the book is therefore brought to the required form (while the case or cover is yet in an unfinished state), held tightly in a press, and the edges scraped smooth with a straight-edged piece of steel, to remove all asperities left by the cutting-plough. The edge is then coated with a liquid composition of red chalk and water; and, while this is setting or partially drying, the gilding-tools are being prepared. The leaf-gold is blown out from the book in which it is sold by the goldbeater, upon a cushion covered with leather, where it is placed out smooth by the aid of a knife. Each leaf is then cut up into two or more pieces, according to the size and thickness of the book whose edge is to be gilt. On the work-bench is a cup containing white of egg beaten up with water, a little of which is laid, by means of a camel-hair pencil, on the still damp surface of chalk and water. The gold is then taken up, piece after piece, by a flat camel-hair brush, and laid on the book-edge. This is done to all the three edges in succession; the book being turned round in the press to bring the successive edges uppermost. After the lapse of a very few minutes the gold has become sufficiently dry and set for polishing, a process which would seem calculated rather to rub off every atom of gold than to polish it. The workman holds in his two hands a long-handled burnisher, at the lower end of which is fixed a very smooth straight-edged piece of hard stone; this he places on the gilt surface, and with his left elbow resting on the workbench, and the handle of the burnisher resting on his right shoulder, he rubs the gold with great force at right angles to the direction of the leaves. No gold is rubbed off, but the whole is brought to a high degree of polish; the compactness of the leaves being such as to allow no chalk-colour or egg or gold to penetrate between them. If the burnisher were worked in the direction of the leaves, the polish would not be so high. The boards of the book are during these processes turned back as far as possible; and when the gilding is completed, paper is wrapped round the gilt edges, to prevent the gold from being soiled in the subsequent finishing of the book.

The covers of books are decorated in a greater variety of ways than the edges. Roan-bound school-books are sometimes 'marbled' outside; a process which bears some resemblance to the sprinkling of the edges. A liquid composition of copperas, potash, water, and any common colouring substance, such as umber, is made. The books are opened, and hung over two bars, so that the boards may be nearly horizontal, and the leaves hang vertically downwards. The liquid colour is then dashed on somewhat in the way before explained, so as to cover the back and sides of the book; the spots or splashes being larger or smaller, according to the mode in which the brush is handled.

A mode of improving the appearance of Morocco leather for the covers of books is not a little striking. Whoever compares the appearance of a piece of Morocco in a slipper or a chair-cover with that presented by a well-bound book will perceive that the former has a series of irregular lines or grooves; whereas the latter has a regular granulated appearance, which is thus produced:—The leather is first wetted and laid on a bench. The workman fastens to the palm of his right hand, by means of a strap passing over the hand, a large flat piece of cork. Then, doubling one portion of the leather over another, so as to bring two surfaces into contact, he gently rubs the upper fold of leather to and fro with the piece of cork; varying the extent and position of the doubling, and the direction of rubbing, so as to let every part of the surface be rubbed against some other part. The effect is very marked; for not only are all the wrinkles removed, but they are replaced by a kind of granulated surface, consisting of a uniform series of minute raised spots. When the leather has been allowed to dry, it retains this texture permanently, and is then applied to the covering of books.

The cotton-cloth with which so large a number of new books are now covered has an ornamental character given to it in three different ways, either before or after it is applied to the boards of the book. One of these is the imprinting, all over the cloth, of a small and uniform pattern calculated to hide the barrenness and stiff uniformity of the threads in the cloth. If the reader has an opportunity of inspecting the backs of many cloth-bound books, he will see that there are a great variety of patterns thus given to the cloth. The process is as follows:—There are machines for preparing the cloth, each of which consists of two cylinders rotating in contact by means of the usual machinery, as in the next cut. The cylinders are engraved with the device which is to be impressed on the cloth, and there are therefore as many pairs of cylinders as there are devices; each pair being fixed to the machine as wanted. By a very ingenious contrivance, a row of small jets of gas is carried through the interior of the lower cylinder, by which it becomes heated throughout. Every kind of stamping or embossing in leather or cloth is more effectively per-

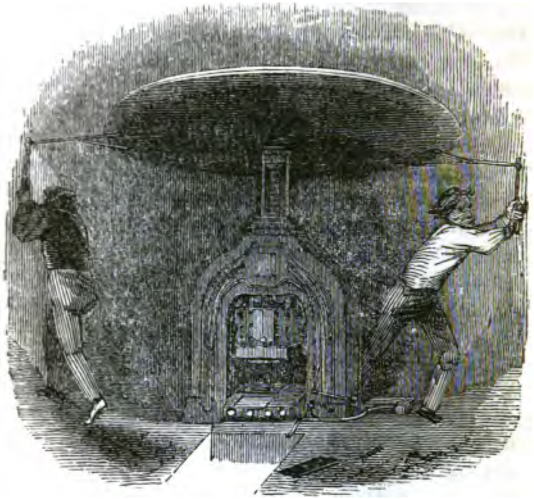


Cloth-embossing Machine.

formed when aided by heat, and it is to afford this heat that the gas-jets are employed. Other machines, on a similar principle, are employed to impress particular designs of which a large quantity may be required. The piece of cotton-cloth, many yards in length, is inserted between the cylinders at its extreme end, and is then, by the action of the machine, drawn regularly between them, receiving its impress as it passes.

The embossing-presses act on a different principle. The device is in this case engraved on a flat thick plate of steel or gun-metal, which is stamped down upon the leather or cloth. The cover or the case for a book is laid flat on a tablet or bed heated with gas from beneath, or else on a counter-die similar to that by which it is to be impressed. The engraved plate (which is in 'intaglio,' like a seal, but not so deep) is fixed to the press with its face downwards, and by manual labour, exerted on very powerful levers, it is brought down upon the cover with such force as to impart its device to the leather or cloth, the device being of course raised, or in bas-relief, like a 'cameo.' There are some instances in which the embossing is done to the leather or cloth before, and in others after, the cover is pasted to the boards; but the action of the machines and the nature of the device are the same in either case.

When we compare a cloth-bound book, or the cheap embossed-roan Bibles now so much used, with an elegant morocco or russia-bound book, we see that the ornamental devices are raised above the common surface in the former case, and levelled below it in the latter. Hence a very different system of working is required. The name of *blocking* is given to the operation whereby the depressed device is given. This is either effected by a number of punches and other small tools used by hand, or by means of a small blocking-press. A jet of gas is so placed as to heat a central compartment, into or against which the tools are placed, whether for lettering or ornamenting, whereby the blocking, or rather 'tooling,' is effected. Sometimes the depressed device is not coated with gold, in which case it is called 'blind-

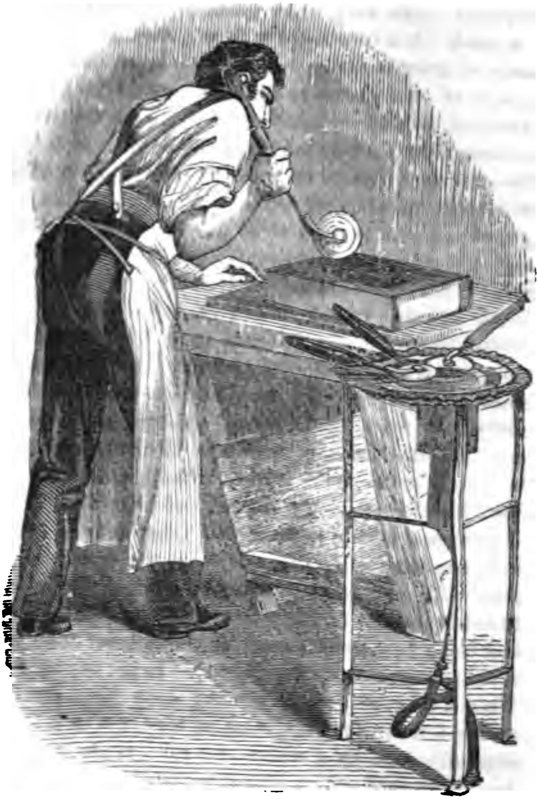


Embossing-Press.

tooling;' in others, gold is laid on the book, and then stamped down with the heated tool. The workman has a vast number of tools, such as rounds, squares, points, scrolls, diamonds, lines, letters, &c., the combination of which, according to the taste which he is enabled to display, produces a pattern. The book is laid on a bench, with its back or sides uppermost, according to the part under operation, and the workman presses the heated tools down on the level surface, leaving a device which is at once depressed and polished. In large or elaborate devices he has a paper pattern for his guidance.

When the device is to be a gilt one, the leather requires certain preparatory processes to fit it to retain the gold. It is first coated with size, then two or three times with white of egg, and lastly slightly touched with a piece of oiled cotton at the time the gold is laid on. The gold is laid on in slips of greater or lesser size according to the pattern; and the heated tools are immediately impressed on it, whereby the gold is made to adhere permanently to the leather. The loose or superfluous gold is then wiped off with a rag,—which rag, we may remark, becomes an article of no small value in the course of time.

All that has been here said of ornamental devices applies equally to the lettering of a book. Where, however, it may be done conveniently, the punches or small devices, instead of being fixed in handles and used singly, are fixed, by means of glue and cloth, to a metallic plate, and thus impressed on the book at one blow by a press. This is then called 'blocking.' In the 'blocking-shop' are drawers and boxes filled with various small devices in brass, which the workman combines according to his taste, and fixes to a flat block or plate. The plate is attached to the upper bed of a press, heated by means of gas within; and the case of the book being introduced beneath, the block is let down on it, and imprints the device, whether it be gilt or 'blind.' Where a fillet, or line, or running sprig forms part of the ornament on the back, sides, or edge of a book, it is frequently done by a wheel or 'roll' in the manner here represented. The edge or periphery of the wheel has the device in relief, and this, being wheeled along carefully over the surface of the book, leaves a corresponding depression.



Decorating a Book.

Such are the principal modes by which a book is decorated. We have been able merely to give a type or general representation of each, and must necessarily pass over minuter shades of operation. The costly bindings in velvet and silk, the gold and silver clasps of expensive Bibles, and all the niceties which the connoisseur in bookbinding regards with such an admiring eye, are exceptions to the general routine of manufactures, which may be passed over in this brief outline.

Having thus, in the foregoing pages, glanced at the chief among those manufacturing details which relate to BOOKS, we shall devote the remaining Chapters of this volume to those which bear most prominently on TRAVELLING; taking, in the first instance, a *Coach* and its appendages as an example of one large class of aids to travelling.

# CHAPTER V.

## COACH-BUILDING; WHEEL-MAKING.

According to the information of Stow, the business of *coach-making* arose more suddenly in England than has commonly been the case in the annals of our manufactures. "In the yeere 1564," says he, "Guylliam Boonen, a Dutchman, became the queene's coachmanne, and was the first that brought the use of coaches into England. And after a while, divers great ladies, with as great jealousie of the queene's displeasure, made them coaches, and rid in them up and downe the countries, to the great admiration of all the beholders; but then by little and little they grew usual among the nobilitie, and others of sort, and within twentie yeeres became a great trade of coach-making." The fashion gained a permanent footing, notwithstanding the opposition of watermen and chairmen, and the vituperation of Taylor the 'water-poet,' who reviled the new-fashioned coach as a "great hypocrite, for it hath a cover for knavery, and curtains to vaile and shadow any wickedness. Besides, like a perpetual cheater, it wears two bootes and no spurs, sometime having two pair of legs to one boot, and oftentimes (against nature) it makes faire ladies weare the boote; and if you note, they are carried back to back, like people surprised by pyrats, to be tyed in that miserable manner, and thrown overboard into the sea. Moreover, it makes people imitate sea-crabs, in being drawn sideway, as they are when they sit in the boot of the coach; and it is a dangerous kinde of carriage for the commonwealth, if it be considered."

Allusion is here evidently made to forms of coaches not now adopted; and indeed we find, on glancing at old prints of the seventeenth and eighteenth centuries, that the coaches had a great variety of forms imparted to them. Leaving these points, however, our purpose is to pass rapidly in review the chief mechanical operations concerned in building a coach or other vehicle.

Perhaps the simplest mode of viewing the construction of a coach is in reference to the materials used. These are principally timber, iron, plated metal, leather, paint, varnish, and woven materials. The main parts of a vehicle are constructed of wood, whether in relation to the body (the part in which the travellers are seated), the under framework, or the wheels. Iron is, however, used in considerable quantity, not only for the springs, but in almost every part of the vehicle, in order to enable the latter to bear the very severe strain to which it is subject. Plated metal is used principally for ornament, such as beadings, &c., in addition to its employment for handles, hinges, and various other small pieces of mechanism. Leather is used for covering the upper part of the body of the best coaches, for suspending the body in its supporting frame, for attaching the horses to the vehicle, and in a small degree for the internal trimmings of the coach. Paint and varnish are of course used for the customary purposes, in preserving and beautifying the surfaces of the wood and iron. Woven materials, such as carriage-lace, fine woollen-cloth, silk, &c., are employed in the internal decoration or 'trimming' of a coach.

It may now be asked whether these various operations are ever carried on under one roof, and by one establishment: or whether, in order to see the different processes of coach-making, it would be necessary to visit as many different tradesmen as there are branches of manufacture. No one establishment makes all the various parts of a coach; and great differences exist in the extent to which the connection of the branches is carried. Some of the smaller manufacturers merely put together the parts which have been procured ready made from other persons, while the larger firms embrace several different departments, whereby the parts of a coach are, for the most part, entirely made within one factory.

The first thing to be done in building a coach—as in building a house or a ship—is to draw the design, to display taste and invention in the plan and proportions, so as to combine comfort with elegance to the greatest possible degree. There must be an architect for a coach as well as for a house or a ship, and he is required to possess inventive ingenuity, as well as knowledge of geometrical forms. The working-drawing or design for a coach is sketched with chalk on a large smooth black board, and on the same scale as the vehicle to be constructed. The party for whom the coach is to be made has thus an opportunity of seeing the plan and proportions, and of suggesting alterations before practical operations are commenced. The elegance and costliness of a well-built private carriage render it quite as much an object of taste as of convenience; and thus the ingenuity of the coach-designer is constantly at work to devise improved forms and modes of arrangement in the various parts of a carriage. In addition to its elegance, too, a coach is constructed in a manner more and more conducive to the comfort of the inmates—a meed of praise which we cannot always give to the prevailing form of hats and coats, for the latter often teach us that fashion is an uncomfortable tyrant.

When the form and proportions are definitely arranged and clearly sketched on the board, a plan is adopted very similar to that observed in building a ship. The pattern of a ship is drawn the full size, and a *mould* is formed of pieces of thin wood, adapted to all the chalk-marks in the sketch, and serving as guides to the shipwright in fashioning the hull of a ship. So it is with the coach-builder. He prepares a *mould* of a coach, that is, he places a series of thin pieces of wood to the chalk-marks on the board, shaping them in such a manner as to guide the saw and plane of the workman hereafter. The chief reason for this similarity in the operation of the shipwright and the coach-builder, so far as regards the commencement of his operations, is found in the tortuous forms of the pieces of wood used in the structure. Without any further allusion to a ship, we may merely observe that there is scarcely a right angle or a straight line throughout a coach. Curvatures of the most remarkable and complicated kind occur, which cannot be expressed in feet and inches; and thus it becomes necessary to have a type, a mould, a pattern of some kind or other, to transfer the required forms from the chalk sketch to the rough wood on which the workman is afterwards employed.

The sketch being formed, and the pattern-pieces prepared in conformity with it, the wood is selected fitted for the purpose. In the coach-factories there are usually two sawpits—one for cutting wood in the 'round,' and the other for 'converting.' The 'round' is the technical appellation for wood just in the form in which it is cut, before being squared, and in this form a large quantity of timber is stowed away. The operations of the sawyer, by which the trees are cut into planks, are of the usual kind, and require no particular nicety.

When the wood is cut into planks, it is 'converted' in the other pit. This term (which is also used by shipwrights in an analogous manner) relates to the cutting of the planks into the required forms by means of the pattern-pieces, and requires much more taste and judgment. A word or two may here be said on the varieties of wood employed by the coach-builder. Ash is used very largely in the construction of coaches; the quality called 'hedge-row' ash is a tough fibrous wood, with which the principal parts of the framework of a coach are constructed; it is not liable to warp or twist, and thus becomes for many purposes a valuable kind of timber. Beech is a cheap kind of wood, never used by builders of the best coaches. Elm is employed for planking in those parts of the body of a coach requiring much strength, as also for the naves of wheels. Oak, in similar manner, is employed in various parts of coaches wherein strength and durability are required. Mahogany furnishes the material for the panels of the best coaches—those broad, smooth, and delicately curved surfaces which form the most conspicuous part of the body of a coach. Spanish mahogany, which the cabinet-maker selects as the most beautiful for his purposes, is not so useful to the coach-builder as the kind called Honduras, on account of the unfitness of its curled and twisted grain to conform to the bending which coach-panels receive. Deal and a few other kinds of timber are used to a limited extent in coaches; but ash and mahogany are the two principal kinds.

The proper timber being selected for the various parts of a coach, it is taken up to the coach-making loft, where the operation of the maker commences. It may be here stated that the term 'carriage' is used by the workmen in a sense different from that commonly employed. We speak indifferently of a *coach* or a *carriage;* but the coach-builders apply the latter term only to the framework which lies beneath or around the body, and which serves both to support the body and to connect it with the wheels, pole, &c. Hence there are two classes of workmen employed, the one called 'body-makers,' and the other 'carriage-makers;' the one employed principally on delicate framework and panelling, the other on stouter masses of wood. Body-makers may be regarded as the principal artisans employed in a coach-factory. They are required to possess a practical knowledge of complicated geometrical forms, and a very accurate hand and eye. The body of a coach is first put into shape by a skeleton framework of ash, every piece of which is more or less curved in one direction or another, and sometimes in double curvature. The meeting edges of the various pieces of wood are seldom at right angles to the surface, and various methods of joining are thereby rendered necessary; in some parts glue, in others bolts, nails, or screws; and in others those kinds of joints known to workmen by the names of 'tenon-and-mortice joint,' the 'lap-joint,' and the 'groove.' In forming the several pieces for the body of a coach, the workman makes constant use of the pattern or mould-pieces, by which he is guided in the curvatures given to the different parts. The actual working of the wood does not differ much from the operation of a joiner, planes and the customary joining tools being alike employed by each. Not only are the skeleton pieces of the framework jointed together with great nicety, but equal or even still greater care is required in preparing the grooves for the reception of the mahogany panels. The panels themselves are brought to the symmetrical and elegantly curved forms which they present, partly by the plane, and partly by the united action of heat and moisture. If a thin plank be wetted on one side and heated on the other, it will speedily become convex on the moistened side and concave on the other; and the workman is enabled to make these forms permanent.

The experience and tact requisite for this department of coach-building have the usual effect on the relation between master and workman; the latter can command a high rate of wages. Coach-body makers, indeed, rank among the highest order of London artisans; the number of first-rate workmen in that branch is limited, and does not appear likely to increase in any great degree.

The reader will then understand that the *body* of a carriage, *i. e.* that part in which the sitters are placed, is made by a class of workmen different from those who make the under part of a carriage; that the wood of which the body is principally formed (in the larger and more important factories) is principally ash and mahogany; that the workman fashions the various pieces by the aid of a pattern-board, as in the process of ship-building; that the actual process of working the wood is a superior kind of joiner's work; and that the operations are conducted in that floor of the building called the 'coach-making loft.' While the body of a coach is thus in process of formation, the other parts are being made by other sets of workmen; the 'carriage-makers' are employed on the complicated mechanism beneath the dody; the smiths are preparing the numerous pieces of iron required in various parts of the coach; and the wheelwrights are making the wheels.

Perhaps we may as well introduce in this place the few descriptions to be given concerning the subject of wheel-making. The business of a wheelwright is totally distinct from that of a coach-builder; no establishment of the latter kind, we believe, being in the habit of making the wheels for their own coaches. But although the operations of the wheelwright are thus not strictly associated with those of the coach-maker, yet both require a little elucidation in connection with the present subject.

A coach-wheel is a remarkable instance of lightness combined with strength; and not less remarkable for the accuracy of hand and eye required in its construction. As a matter of principle, a large flat circular piece of wood, with a hole in the centre, would form a wheel; and in many countries forms the only kind of wheel used at the present day; but practice shows that a much smaller quantity of material is capable of being wrought into a wheel excelling not only in elegance, but also in durability, such rude productions. The essential parts of a modern wheel are the *nave*, the *spokes*, and the *felloes*, corresponding to the centre, the radii, and the circumference of a circle. The nave is a short block of wood, usually elm, forming the middle of the wheel, and pierced with a hole to receive the axle or axle-tree. The spokes are bars of oak, radiating from the nave at equal distances one from another, and extending to equal distances from the nave. The felloes are circular segments of ash, framed on the extremities of the spokes, and joined one to another so as to form a circle. To these parts must be added the *tire*, an iron hoop which binds all the felloes closely together.

The mass of elm intended for the nave is turned ot the required dimensions and shape in a lathe, and is hollowed within to receive the axle. It is then fixed in a kind of groove, with its axis horizontal; and the mortices or holes are chiselled out, for the reception of the end of the spokes. This is a nice and difficult operation, requiring a practised eye for its proper execution, on account of the peculiar direction in which the spokes radiate from the nave of a wheel. If we stand at a short distance behind a carriage, we shall perceive that the wheels are not flat, but that they are concave on the outer surface and convex on the inner; the lower spokes are nearly in a vertical position, while the upper spokes branch out at a considerable angle from the vertical. There are various reasons for this form, some of which relate to the strength of the vehicle, some to the increase of room for the body of the coach without increasing the width of the track of the wheels, and some to the preservation of the coach from splashing. The holes for the spokes have therefore to be chiselled in conformity with this 'dishing' of the wheel, as the conical form is called; and not only so, but half the spokes are placed nearer to one end of the nave, and the other half to the other, for the sake of increasing the strength, and thus the holes have to be made at different parts of the nave's length.

The pieces of oak for the spokes are brought to the wheelwright in lengths of about four feet, and are then shaped by hand to the light and elegant forms with which we are familiar. The length of the spokes must of course depend on the diameter of the wheel. The front wheels of a modern coach are from forty to forty-four inches in diameter; and the hind wheels from fifty to fifty-six inches. The front wheels have usually twelve spokes, and the hind wheels fourteen. A plane, the usual aid to a workman in giving a smooth surface to wood, cannot be employed in preparing the spokes, on account of the varying curvatures which they present; a small cutting-tool called a 'spoke-shave' is the principal instrument employed. One end of each spoke is formed into a tenon to fit the mortice-hole in the nave; and the spokes are fixed by the operation of 'speeching,' or 'spoking,' represented in the next cut. The nave is placed in a kind of socket at a short distance above the ground, in a part of the workshop where a cleft is made in the floor to receive the spokes as the nave is gradually turned round; and the spoke is then driven into the hole prepared for it, by repeated blows with a mallet. The spokes are partially shaped before being driven into the nave, and are finished afterwards.

The rim of a wheel is formed of several distinct pieces called *felloes*, each felloe being long enough to receive the ends of two spokes. The ash of which they

are formed is in short roughly-curved pieces, and these are afterwards shaped to the proper form and dimensions by means of pattern-boards and various cutting tools. When the felloes are formed, they are fixed firmly on a low bench, and four circular holes are drilled in each piece, two to receive the ends of the spokes, which are formed into cylindrical tenons, and two for joining the felloes end to end. For the latter purposes, short cylindrical pieces of oak, about three inches long, and called 'dowels,' are made, and being fitted to corresponding holes made in the ends of the felloes, serve to unite them one to another. Wedges are inserted when required, and the whole become thus firmly combined in the form of a wheel.

But the piecemeal manner in which the circumference of the wheel is thus made up would ill qualify it for service, were not a strengthening hoop of iron fitted on. Formerly straps of iron, called 'strakes,' were applied to the surfaces of the felloes, covering the joints; but after a time an improved method came into use, which consists in the application of a solid iron hoop, which is put on the wheel while hot, and by shrinking as it cools forces the whole of the framing together into a firm body. The process of 'hooping' or 'tiring' a wheel is represented in the next cut. There is a circular flat iron plate placed in a horizontal position, with a vertical axis or stem rising from its centre. The wheel is placed down on this plate, the concave or 'dished' side downwards; the nave resting in a hole in the plate, and the wheel being fixed to the central stem: Immediately adjoining this circular plate is a small furnace adapted for the reception of the hoop or tire, which has been previously welded to the required size; and when the tire is brought to a proper heat, it is taken from the furnace, and by means of iron instruments fitted to the circumference of the wheel. The diameter of the tire is such that it would not fit on the wheel while cold, but being expanded by heat, it encompasses the wheel, and gradually clings tightly to it as it gets cold. To aid in this, two men beat the tire with powerful hammers, while the two others cool the iron by sprinkling it with water. Iron pins are subsequently driven through the tire and felloes, one on each side of every joint, the points being securely riveted inside the felloes. Iron hoops are also placed round the projecting parts of the nave, to enable it better to resist the strain to which it is subjected.

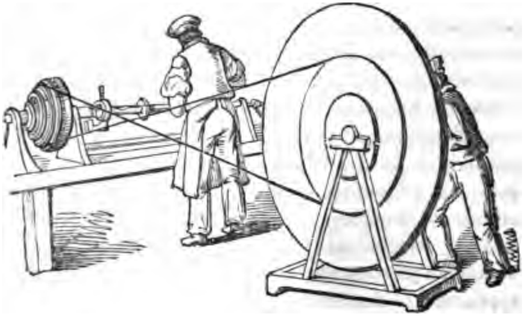
This brief notice will serve to convey some idea of the manufacture of the wheels of a coach. The process of painting them is one which need not be noticed here; we shall therefore transfer our attention again to the coach manufacture. The framework by which the body of a coach is connected with the wheels is, as was before observed, called the 'carriage,' and is the production of a class of workmen called 'carriage-makers.' These artisans are not required to produce such delicate work as the 'body-makers,' the masses of wood being much more heavy, and the joints fewer in number. Ash and elm are the principal kinds of wood which they use. It would be quite impossible, and, if possible, wholly uninteresting, to enumerate here all the various pieces of wood which constitute the framework of a carriage, some to connect the fore and aft wheels in pairs, some to connect the pairs of wheels together, some to support the body, others to support the coach-box, others again for the footman's standing-place behind, and others for the attachment of the horses to the coach. It is necessary to mention, however, one peculiarity in which a four-wheeled coach differs from many other forms of vehicle. In some coaches the body is connected with the under framework by pliable braces of leather attached to the springs; and in this case, the framework which supports the fore and hind springs is connected together by a long central piece of timber plated with iron, and called the 'perch.' An iron perch, called a 'crane-neck,' is sometimes used instead of a wooden one, and is shaped so as to enable the coach to turn somewhat more readily in a narrow street or road, an advantage, however, which is gained at the expense of greater weight of material.

As to the mode in which the carriage-makers proceed with their work, little need here be said. The planks and pieces of ash are roughly shaped by the saw, and are then worked to the proper contours, partly by planes, but much more by tools more or less resembling spoke-shaves.

The iron-work required in coach-building is applied to various parts of a vehicle, and at different periods in the progress of the carriage towards completion. After the perch for a coach is made, and before it is fitted to the other parts of the framing, the smith takes it in hand, and fits side-plates of iron to it, for the sake of increasing the strength. In like manner many other parts of the vehicle, as soon as the woodwork is to a certain extent completed, are bound, hooped, or strengthened with iron in various different ways. All the iron for these purposes is forged out of small bars to a form nearly approaching that required, and is then either turned or filed to a regular surface. Where a perch is made entirely of iron, great muscular force is requisite in welding the different pieces into one mass. Indeed, both strength and skill are required in a coach-smith, for he has to work large and heavy bars of iron into forms containing several unequal curves, and varying greatly in thickness. There is a curious gradation of talent, and consequently of wages, observable in the operations of coach-smiths. There are the *forge-men*, the *hammer-men*, and the *vice-men*, all earning different amounts of wages. A forge-man and a hammer-man generally work together, the latter being subordinate to the former, and indeed often paid by him. The forge-man is the responsible workman; he judges of the quality of the metal, regulates the curvatures, and exercises his skill in combining elegance with strength in the various iron-fittings required for the coach. The hammer-man aids him in his work, using the sledge-hammer under the direction of the forge-man, blows the bellows, keeps up the fire, and performs other offices subordinate to the labours of the forge-man. The *vice-men* are those smiths whose work is at the vice instead of the anvil. They file and finish the various pieces of iron when forged, and prepare the iron for being fixed to the woodwork of the coach.

One of the most carefully executed parts of the iron-work of a modern coach is the *axle* or *axle-tree.* The axle is the piece of wood or iron which serves as a centre for the motion of the wheels. It was formerly made wholly of wood, and was then generally termed an axle-tree; but now that metal is frequently used instead of wood, the word 'axle' is more frequently used alone. Axles used formerly to be fixed firmly in the wheels, and to revolve beneath the vehicle; but now they are more frequently so made that each wheel revolves separately on them. The first iron axles introduced were of a rude construction, but successive improvements have brought them to great perfection. The axle consists of three parts: the two *arms*, which pass into the naves of the wheels; and the *bed*, or central part, which connects the two arms together. At first, a hoop or ring was put within the hollow of the nave, to prevent the too rapid wear of the wood by the friction of the axle; but now the nave is lined with an accurately-fitted iron box, capable not only of receiving the axle with little friction, but also of containing a reservoir of lubricating oil. A modern construction, known by the manufacturers as Collinge's patent axle, is a very ingenious and complete application of this method. The box for placing within the nave of each wheel is first moulded in cast-iron, and then turned in a powerful lathe to a very beautiful degree of smoothness, especially on the inner surface, in which the axle will work. These axles are made by means of a large lathe, worked by one or two men at a wheel, as in the annexed cut. The tools for turning the metal, as well as the general mechanism of the lathe, require considerable strength and power. In order to make the axle work more freely in the box, the inner surface of the latter is 'case-hardened,' that is, by a peculiar action of charcoal aided by heat the surface of the iron is to a small depth converted into steel, which, being harder than the original iron, is susceptible of receiving a finer surface, and of withstanding the wearing effects of friction.

The *springs* form another and very important part of the metal-work of a coach, and require a brief notice in this place. The object of a spring, whatever be the substance of which it is formed, is, by its elastic action between the wheels and the body of the coach, to diminish the concussion and irregular motion occasioned by the passage of the wheels over uneven ground. Leather might be used with a slightly elastic effect; wood is sometimes used in light one-horse vehicles; but iron or steel is the universal material for the springs of modern English coaches, and is generally applied in the form of elastic plates. The forms given to these steel springs are exceedingly varied, and contribute not a little to the general elegance of a coach. The earliest springs were formed of a single plate of steel; but in modern manu-



facture several plates are laid one on another, all bound in close contact, and yet free to bend independently of each other, by having the ends loose. The steel employed is prepared expressly for the purpose, and is brought by the rolling-mill to the thickness of about a quarter or three-eighths of an inch, and from one and a half to three inches wide. A compound spring, formed of several parallel plates, is hooped or bound together with an iron hoop shrunk on hot, and riveted. If it be a curved spring, the external plate is of course longer than the others, and is formed of thicker steel. All the plates are formed in a similar way. A piece of steel is cut to the required length, tapered and prepared at each end, and one or both surfaces are then 'middled,' that is, slightly hollowed by hammering. Near each end a slit is made about an inch long, in which a small rivet-head, attached to the next adjoining plate, may work. When four or more of such plates are combined, and hooped tightly in the centre, the ends are free to yield when any pressure is felt, and thus the pressure becomes equally shared by all. We may illustrate this action by the following supposition:—let a dozen laths be laid one on another, and bound or riveted tightly at both ends; they could not then be bent very far without fracture; but let them be bound only in the *centre*, and the whole will bend nearly as easily as a single lath, because the ends of each lath are free to conform to the curvature produced by the bending.

The next cut shows the mode of forming one of the numerous variety of coach-springs. The assemblage of plates, after being prepared separately and laid one on another, is fixed firmly in a vice, and an iron band or hoop is hammered on, till it clasps the spring at the thickest part with great closeness. Before this is done, each plate is subjected to the action of the fire. It is first heated to a certain temperature, then plunged into

water, then heated again till such a temperature is acquired as will ignite a small stick. These processes of 'hardening' and 'tempering' are requisite to the subsequent action of the spring. The plate is then 'set,' or hammered perfectly straight; then filed in all the parts which will be visible; and the plates are in this state ready to be combined in the form of a spring. The springs are built up much in this manner, whatever be their shapes or designations. As to the technical distinctions of the 'single-elbow spring,' the 'double-elbow spring,' the 'C spring,' the 'S spring,' and many others, we need merely here remark that they are various forms, adapted for different kinds of carriages, some for the coach, some for the phaeton, some for the cabriolet, &c., but that all are produced by similar trains of operation.

With respect to the numerous other pieces of iron-work required in a coach, and known to the workman by the technical names of plates, loops, stays, hoops, clips, bolts, steps, treads, joints, jacks, shackles, &c., all that need here be said is that they are specimens of smith's work requiring considerable skill and ingenuity.

The labours of the smith alternate, or rather are simultaneous with those of the 'body-maker' and the 'carriage-maker,' and therefore we cannot profess to follow the precise order of proceeding. At certain stages in the progress of the woodwork various pieces of iron are worked into their proper places, before other pieces of wood are connected together. This is particularly the case in 'carriage' mechanism beneath the body, in which a considerable quantity of iron is employed, the adjustment of which alternates with the work of the carriage-maker.

A remark may be applied to the 'coach-carver' similar to that applied to the 'coach-smith.' His labours are directed not to the coach as a whole, but to the several parts of it during their progress. A coach-carver must necessarily be a man of some taste, even if he only executes patterns designed by others, but much more so if he designs them himself. His operations are of two different kinds, the simplest being that of carving the beadings and mouldings of the body or carriage, and the more elaborate that of producing the foliage and ornamental tracery which add so much to the beauty of a well-built coach. In 'state-coaches' this species of decoration is profuse and very costly;* but every coach, however simple, contains more or less carving. The tools of the coach-carver resemble those of carvers in general: they are more distinguished for their excellence than for their number or their size; and the workman depends more on his own taste and invention than on any prescribed rules of proceeding. The coach-carver is indeed an artist, and as such is highly paid.

One of the most remarkable operations in the construction of a coach is that of covering the upper part with leather; remarkable, we mean, in respect of the manual dexterity required. The panels, the quarters or upper panels, and the roof of a coach are very thickly painted, both for beauty of appearance and for durability. But the higher class of coach-builders do not trust exclusively to this external preservative; they cover the roof, and the upper part of the front, back, and sides, with leather, previous to the process of painting. It might be supposed that a hide of leather is for this purpose cut into pieces, one for the roof, one for each side, and so on; but the whole is covered with one hide, free from any joints or divisions whatever, and yet made to adhere closely to the woodwork in every part without folds or wrinkles. The hide, which is of a large size and sound quality, is first thoroughly moistened throughout and thrown over the top of the coach, the edges hanging down on all sides. The currier then rubs or presses it down all over the roof, until it lies close and even in every part. He next proceeds to one of the sides, and in like manner rubs and scrapes the leather till all irregularities disappear. The leather is in that soft and pliable state, that it will yield to the movement of the tools, and enable the workman to fit it to every part of the coach with perfect closeness. A little consideration must show that a superfluous fold of leather will occur at each corner; yet by working it towards a central point at the back or front, the currier succeeds in erasing or pressing out all irregularities, and in producing a surface sufficiently flat and smooth for the subsequent operations of the painter. The division between the upper and lower portion of a coach is usually covered by beading of some kind or other, and the leather is trimmed or cut to this line of division. This operation of covering a coach is as important as it is curious; for if a puncture be made through the leather, and rain-water enter even in minute quantity, the surface will be uneven and disfigured.

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* The carving of the present Royal state-coach of England, which was executed about eighty years ago, cost two thousand five hundred pounds.

The other portions of leather required in a coach need not much description. They consist principally of bands and straps of various kinds. The leather or hide is laid out flat on a board and cut to the required shapes by means of sharp knives. Pieces are stitched together, or buckles, loops, rings, or straps are fastened to them, in the same manner as harness-work generally is done. The workman sits at a low bench, and holding the piece of leather on which he may be at work between a pair of clams or boards, uses the awl and the sewing-twine in the same manner as the boot-maker. A horse's collar, and the general harness for a saddle-horse, do not come under the manufacturing arrangements of the coach-builder; but in many of the large establishments, all the articles of leather required, either for the coach itself or for its attachment to the horses, are made within the walls of the building. A mode of employing leather in which much neatness and dexterity are required, is in covering the iron rails or bars which occur in gigs and phaetons, and other forms of private carriages. The leather, before being japanned or painted, is cut into strips, corresponding with the length and circumference of the rails to be covered, and is then tightly fitted on in a moistened state, the joints and angles being worked up with much nicety, and the meeting edges being stitched closely together.

A department of the coach-making operations, very different from those which relate to the working of wood, iron, and leather, is that in which the painting, varnishing, and polishing are effected. The 'painter's-loft' is one in which a coach remains for a considerable period, and in which it receives no small share of its beauty of appearance. 'Coach-painting' is distinguished from ordinary house-painting by the large number of separate coats of paint laid successively one on another, and by the high degree of purity and polish given to the surface, rather than by any difference in the materials employed. The surfaces, whether of ash, oak, elm, deal, mahogany, iron, or leather, are coated so thickly with paint, that the materials themselves are effectually concealed. The paint is formed of the usual mineral colours, mixed with linseed oil and turpentine; and the varnish employed is that prepared from gum-copal, which, though slow in drying, is very durable.

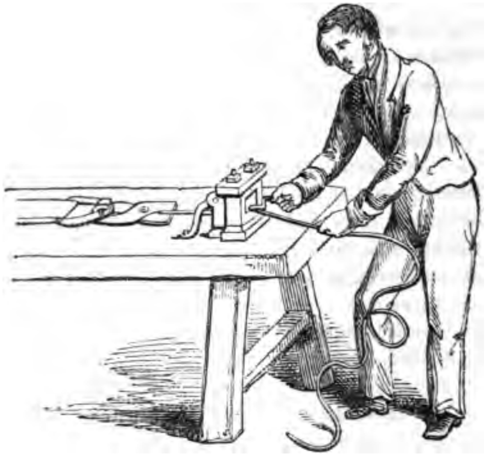
The principal parts of a coach, such as the panels, the doors, the quarters, &c., receive as many as twelve or fifteen different coats of paint, each one being dried before the next following one is applied, and the whole being repeatedly smoothed or polished with rotten-stone, pumice, and similar substances. The earlier coats, as in house-painting, are termed the 'priming,' and are intended to form the foundation on which the subsequent coats are laid.

The earlier coats of paint are formed of white-lead and litharge, to which succeed many coats of white-lead and yellow-ochre. When this body of paint has been dried and smoothed, the layers of green, brown, yellow, or other selected colours are applied to those parts which are not customarily black, while black paint is laid on the parts just mentioned. A sufficient body of paint being thus laid on, the roof, the upper panels, and the sword-case (a protuberance at the back of a coach, introduced when gentlemen carried swords) are coated with several layers of black-japan, and the other parts of the coach receive six or eight coats of copal-varnish. The final process of polishing is deferred for some considerable time, to ensure the previous hardening of the varnish.

The painting of the wheels of a coach is done either by the coach-builder or the wheelwright, according to circumstances: but wherever it be effected, the process is nearly the same as for the 'carriage' part of a vehicle. The part of the coach-painter's work which requires the largest amount of care and neatness is that of 'picking-out,' or painting fine lines, scrolls, &c. of one colour on a groundwork of a different colour. That portion of the painting which relates to the heraldic arms and crests is altogether distinct from the rest, and is the work of a higher class of artisans called 'herald-painters,' whose services are paid for at a high rate. The herald-painter can lay no claim to comparison with the portrait-painter or the landscape-painter; but still, the accuracy of design, the neatness and clearness of outline, and the vividness of colour which he must display, require far more taste than that displayed by coach-painters, and give a higher value to his time.

Nothing can exceed the delicacy, the elegance, and the attention to personal comfort displayed in the interior fittings of a pleasure-carriage. There is considerable taste displayed in selecting not only the material, but the colour of the coach-trimmings. The principal materials employed in this manner are fine Spanish cloths, rich, plain, and embossed silks, embossed leather, richly woven lace, and horse-hair for stuffing cushions. The cloth is of the finest kind, and the silk is woven expressly for these purposes at Spitalfields. The lace employed is made sometimes of worsted, sometimes of silk, and in other instances of both combined, and it is used as a binding or edging for various parts of the interior; the finest is called 'broad-lace;' the next is termed 'pasting-lace,' about half an inch broad, and is employed to cover and hide rows of tacks; and another kind, called 'seaming-lace,' is used to cover seams and edges. The roof, sides, and various other parts of the interior of a coach are first brought to a level surface by wadding and canvas, and are then lined with cloth or silk. Cushions are covered with cloth, silk, or morocco leather, and are stuffed with horse-hair. The bottom of the coach, and the folding steps which are shut up within the coach, are covered with carpet; and the neat appendages to the doors and windows are trimmed with cloth, lace, &c. in various ways. All these operations resemble very much those of the upholsterer, the cloth, lace, silk, and carpeting being in some places sewn and in others tacked down in their places. There is also a part of the *exterior* of a coach on which the trimmer is engaged, viz., the 'hammer-cloth.' This is a cloth covering to the coachman's seat, and is principally used for the more elegant kinds of coaches. The cloth of which it is formed is stiffened at the back, so as to enable it to fall in graceful folds. The upper and lower edges are trimmed with broad and rich lace; and the most conspicuous part of each side has usually an embroidered or chased crest. Temporary covers of oil-skin or some analogous substance are provided for the preservation of the hammer-cloth in wet weather.

A glance at the external appearance of a private carriage will show that iron is by no means the only metal employed in its construction, although it is by far the most important. Beading, plates, locks, hinges, handles, rings, buckles, crests, and ornaments of various descriptions, are made of one or other of the metals susceptible of receiving a good polish and of presenting a pleasing appearance. Brass is the principal metal employed for such purposes, or iron plated with a thin sheet of brass, where strength is required. Copper is slightly employed; so likewise is a white alloy of copper called 'white brass,' 'albata,' or 'German silver.' A considerable quantity of semi-cylindrical beading is used in various parts of a coach; and this is formed in a simple manner. An orifice is formed in an iron or steel plate, the exact pattern of the cross-section of the beading; and into this opening the end of a narrow slip of sheet-metal is introduced by a workman, as in the annexed cut. The end is seized by a kind of pincers on the other side, which are then drawn backwards by means of a winch at the farther end of the bench. The slip of sheet-metal is thus drawn forcibly through the pattern-hole in the plate, and acquires the required semi-cylindrical form. The metal is made very hot by the compression it undergoes. The concave side of the beading is afterwards filled in with some soft kind of metal, and is provided



with points or studs for fixing it to the coach. Sometimes the beading is made of copper, in which case it is afterwards painted; sometimes of brass, if to be left exposed and bright; while for the best coaches the beading is made of a strip of sheet-copper which has had a sheet of thinner silver united firmly to it by pressure in a flatting-mill: in this case, of course, the beading is drawn with the silver side visible.

The operation of *plating*, it need perhaps hardly be observed, is that of covering some of the cheaper metals with a coating of silver, with a view to give to the article both a beauty of appearance equal to that of solid silver and a degree of strength not possessed by silver. Many articles of coach furniture are prepared in this way, the silver being first formed into leaves, sheets, or ribands, and then firmly united to the surface of the cheaper metal by a peculiar application of heat and dexterous manipulation.

# CHAPTER VI.

## SHIP AND BOAT BUILDING.

THE building of a ship, instead of being one peculiar and distinct occupation, calls forth the ingenuity of a large number of different manufacturers; some of whom work in metal, some in wood, some in rope, some in woven cloth, &c.; and some of these are again subdivided into many branches.

In taking a rapid glance at these occupations, it will be convenient to notice first the kinds of boats and vessels made by the ruder nations at the present day, and by our own countrymen in past ages; and then follow the routine of processes incident to the building of a merchant ship or a ship of war at the present day. Various appendages to the ship will then conveniently come under consideration in the subsequent chapter.

The boats or canoes of rude nations bear strong marks of resemblance one to another, not only in different parts of the earth, but in different ages. The reason for this is a very obvious one, viz., that the materials out of which a hollow shell, capable of floating on water, might be constructed, are within the reach of most infant nations, such as a tree to be hollowed within, or reeds to be twisted together and covered with a skin. The ancient Britons used boats or canoes belonging to both these classes. The coracles of our ancestors were seen on the British rivers at the time of Julius Cæsar's invasion; and were constructed of wicker-work covered with hides. The Irish name *curach*, and the Welch *corwgyl*, probably point to the use of similar boats in Ireland and Wales at the present day; for Dr. Southey remarks, in his 'Lives of the British Admirals,' that "Coracles thus made, differing only in the material with which they are coated, and carrying only a single person, are still used upon the Severn, and in most of the Welch rivers. They are so small and light, that when the fisherman lands he takes his boat out of the water and bears it home upon his back. In the management of such slight and unsteady vessels great hardihood and dexterity must have been acquired, especially in a climate so uncertain and in such stormy seas as ours."

That the Britons were acquainted with the mode of constructing boats, or rather canoes, from the hollowed trunks of trees, many evidences remain to show. In a morass called Lockermoss in Dumfries, Scotland, an ancient canoe was dug up in the year 1736, with a paddle near it; the canoe was about seven feet long, and dilated to a considerable breadth at one end. Another canoe, hollowed out of a solid tree, was seen by Mr. Pennant near Kilblain; it was about eight feet long by eleven inches deep. In the year 1720 several canoes of similar construction were dug up in the marshes of the river Medway, above Maidstone, one of which was still in such a state of preservation as to be used as a boat for some time afterwards. On draining Martine Muir, or Marton Lake, in Lancashire, some years ago, there were found, embedded in the bottom of the lake, eight canoes, each made of a single tree. The oak of which these several canoes were made was found on examination to be remarkable for the free grain of the timber; insomuch that several millwrights and carpenters have expressed their opinion that the oak was of foreign growth, and the produce of a warmer country. To this opinion Dr. Southey objects, "That the canoes could not have been brought there from any warmer country seems certain; and if any inference can be drawn from the grain of the wood, as indicating its growth in a warmer climate, it would seem to be that these canoes were made when the climate of this island was warm enough for elephants, hyænas, tigers, hippopotamuses, and other inhabitants of southern countries whose remains have been brought to light here."

The most favourable opportunity for examining the canoes of the ancient Britons is afforded by the specimen now deposited in the British Museum, and which was dug up in Sussex about seven years ago. A full description of this canoe, and of the place where it was found, has been published in the 'Archæologia,' from the pen of Mr. Phillips; and from this account we shall borrow a few particulars.

The canoe was found in a ditch or drain near the village of North Stoke, and not far from the left bank of the river Arun, from whence the town and castle of Arundel are named. The Arun winds round a meadow which appears to have been once covered by water, and in the midst of this meadow, imbedded in what seems formerly to have been a creek or drain, the canoe was found. One part of the canoe had been for a long time visible at about two feet below the surface of the water, and had been used as a support for one end of a flat wooden bridge which crossed the creek from one part of the meadow to another. It having been deemed desirable to make some improvements in the draining of the meadow, this canoe, which had hitherto been deemed nothing more than the trunk of a fallen tree, was brought to light. Eleven horses were required to drag the canoe from its muddy bed; and it was then found to be a hollowed oak trunk, thirty-five feet long, about two deep, and four and a half wide, the thickness of the sides and bottom being generally about four or five inches. There are three bars left at the bottom at different distances from each other, and from the ends, which seem to have served the double purpose of strengthening the bottom and giving firm footing to those who worked the canoe in the water: they are too low and narrow to have served for seats. After stating various reasons for supposing that this canoe was made by the ancient Britons, and that it had lain undiscovered in that quiet part of the country for the intermediate ages, Mr. Phillips remarks, "That in some very early period they (the ancient Britons) should have recourse to the mode in which the canoe, the subject of this paper, was made, to enable them to float upon their rivers for various purposes, though not recorded in their imperfect history, would have been but in conformity with what is known of the like invention by many other people in a similar degree of civilization; and it is adverse to reason to suppose that it should ever be done after the use of iron tools in dividing trees into planks, and the advantage of constructing vessels with wood so divided, became known and practised." This canoe was presented to the British Museum by the Earl of Egremont, on whose estate it was found.

In many parts of the world at the present day canoes hollowed out of trunks of trees form the recognised boats of the natives. There is a tribe of Indians on the banks of the river Colombia in America who live almost wholly by fishing, and the canoes which they make for this purpose are of the following character :—They are upwards of fifty feet in length, cut out of a single tree, either fir or white cedar, and capable of carrying thirty persons each; they have cross pieces from side to side about three inches thick, and the gunwale of the canoe curves outwards, so as to throw off the surges of the water. In managing these canoes the Indians kneel two and two along the bottom, sitting on their heels, and wielding paddles from four to five feet long, while one sits in the stern and steers with a paddle of the same kind. The fearless unconcern with which the Indians manage these canoes, not only in moderately swift rivers, but even in boisterous seas, is said to be very striking. Should a surge throw the canoe upon its side and endanger its overturn, those to windward lean over the upper gunwale, thrust their paddles deep into the wave, apparently catch the water and force it under the canoe, and by this action not merely regain an equilibrium, but give their bark a vigorous impulse forward. Other tribes of Indians in the same locality, but unaccustomed to the regular use of canoes, adopt a very simple and primitive plan of providing a temporary bark: they procure the skin of some animal which they may have shot, extend it out flat, fasten sticks across from side to side in different parts, and place it on the surface of the water: the sticks prevent the sides from collapsing; and the skin, by sinking or bending in the central part under the weight of the rower, forms a recess or hollow in which he can sit.

Instead of hollowed trunks of trees, many rude nations make canoes, or rather rafts, of several solid trunks laid side by side, and fastened together. Such is the *balsa* of South America, a name derived from that given to the tree of which the raft is made, and which is of a white, light, and spongy character. The balsas are, or were, used by the natives on the shores of the Guayaquil river for fishing, for trading, and for passage. The logs, sometimes as many as nine in number, are fastened to each other only by withies, with which the cross logs are also lashed to them, yet so securely as seldom to give way. The thickest log of the balsa is placed so as to reach farther than the others: at the stern another log is lashed to this on each side, and others to these, till the intended number be completed; the large log thus serving as a stay and foundation for the others. The larger sort of these balsas usually carry about twenty-five tons, without endangering the cargo by the too profuse access of sea-water; because, from the peculiar manner in which the logs are attached one to another, the whole assemblage accommodates itself to the motion of the water, and thus prevents the splashing which is so liable to affect a rigid and water-proof boat. These balsas work and ply to windward like a keeled vessel, and keep their course before the wind very accurately: this is effected by the use of some large planks called *guares*, three or four yards long and half a yard broad, which are set up vertically both at the stem and stern: by moving these boards in different directions, as occasion may require, the balsa is made to 'sail large,' to 'tack,' to 'bear up,' or to 'lie-to' (to use nautical phrases), with tolerable ease.

If the log-raft just described bears some similarity in material to the hollow-trunk canoe, there is also some resemblance, in lightness and frailty, between the ancient coracle and the birch-bark canoe of modern America. Many of the Indians on this continent, as well as the white traders who navigate the innumerable lakes and rivers of the interior, are accustomed to use canoes made of birch-bark, sewn together with fibres of the spruce fir, and coated with a resinous or gummy substance which exudes from the pine-trees of that continent. The material used is so extremely light, that a canoe thirty or forty feet long, and capable of accommodating eight or ten men, and of bearing a freight of four tons, can itself be easily carried on the shoulders of six or eight men.

Many of the South Sea Islanders are accustomed to use boats called *ivahas*, and another form called *pahies*, in their warlike and trading expeditions from island to island; but as these vessels are built of planks extending upwards on either side of a central keel, and have a kind of deck, they form specimens of a more advanced stage in the art of boat-building, and do not lie within our present limits.

In proceeding next to speak of English ship-building, it may be well to give some idea of the appearance of the great ship-yards at which merchant-vessels are built.

Such a place, then, presents a busy scene to the eye.

On all sides are seen workmen plying the ingenious hand, and the lusty arm too, in the operation of ship-building; some standing on scaffolds at the sides of the ships; others 'converting' the timbers, that is, sawing them to the required shapes; some conveying or superintending the conveyance of timbers from one place to another; some stripping off the old copper from ships under repair; some bringing new sheets of copper to supply its place; smiths in this spot, mast-makers in that; and scores of others which it would be no easy matter to enumerate.

One of the shops or rooms in such a yard is the office of the ship-draftsman, who is a kind of architect, employed in drawing the plans and arranging the forms and dimensions of ships preparatory to the operations of the shipwrights. In this room are a few small models of ships, together with the necessary apparatus and drawing instruments for preparing the plans on paper. The operations of the ship-draftsman are, as we shall explain presently, much more of a mental than a mechanical character.

Another is the *mould-loft* or *moulding-loft;* a very large and wide room, lighted on both sides by windows. The floor of this room is flat, smooth, and clean, and is chalked in every imaginable direction with lines, some straight and others curved, intersecting each other at angles of different degrees. A part of this floor, free from chalk lines, is separated from the rest by a ledge, and on this part are fixed carpenters' benches and stools, with the necessary arrangements for sawing and preparing woodwork. It is evident, at a first glance, that the chalked floor is a kind of sanctum, a place not to be defiled by the tread of dirty shoes. Over head is seen, resting on cross-beams, a large assemblage of pieces of thin wood, in most cases long, narrow, and curved. The operations carried on in this room are midway between that of preparing the drawing and that of actually building the ships. The purposes of the chalk marks on the floor and of the thin pieces of wood will be explained farther on.

Another shop is generally appropriated to 'oakum-spinning.' When the various cables, stays, shrouds, ropes, &c. belonging to a ship have gone through their term of service, and are no longer strong enough to be used, they are cut up into pieces, and then pulled asunder, all the hempen threads being loosened and disentangled one from another. In this state the hempen threads are called *oakum*, which is of different qualities, according as the original rope was or was not tarred. This oakum is sent to the oakum-shop in bundles or hanks, and boys are then employed to roll—or, as it is termed in the yard, 'spin'—it into loose portions called 'threads.' A small bundle of fibres is rolled by the hand on a sloping board, till it assumes the form of a loose irregular kind of rope, averaging probably half an inch in thickness. These 'threads' of oakum are subsequently driven into the crevices or seams in the outside of a ship, to prevent the entrance of sea-water.

'Trenail-cutting' is another occupation, which requires either a separate shop or a clear space to conduct

it. A trenail is a wooden substitute for a bolt or nail, and is regarded as a thing of much importance in ship-building. The frame-timbers of a ship, forming its skeleton, are, as we shall hereafter explain, covered inside and out with thick planks, and these planks are fastened to the timbers almost wholly by trenails, the copper bolts employed being comparatively few in number. These trenails, so far from being made of any odd piece of waste wood, are formed of the soundest oak, whose grain is straight and regular. They vary in size from a foot and a half to three feet in length, and from one to two inches in diameter, according to the size of the vessel, or to the part where they are to be employed. The pieces of oak which may be selected for this purpose are first sawn to the proper length; the trenail-makers then rip each piece into a number of smaller pieces, and finally reduce them to a tolerably cylindrical shape by means of spoke-shaves, occasionally passing a ring over each piece to regulate the diameter. These trenails are generally kept for many months, to season, before they are employed in the ship. Those pieces of oak whose shape or direction of grain does not qualify them for trenails, are cut into wedges, for the use of the shipwrights in various parts of their operations; and those which will not be available even as wedges are consigned to the billet-heap.

The smithy is an important part of a ship-yard. The articles made in this shop do not comprise either the ships' anchors or the chain cables, for the making of these are distinct trades, never carried on in a private ship-building yard; but they consist of the numerous other pieces of iron-work used in the construction of a ship. The most important of these, perhaps, are the iron *knees*, which connect the beams beneath the deck of a ship with the sides, and which are a kind of bracket, with branches extending in horizontal and vertical directions, perforated for the reception of bolts. These knees are made of iron bars or plates welded together to the proper thickness and width, and fashioned to the required shape. Smaller articles, in great number and variety, are made in a similar manner, the operations being conducted almost precisely in the same way as in a common smith's shop, but on a larger scale. The fierce fires of small-coal built upon the ground, the bellows for exciting the heat, the anvils, the huge sledge-hammers—some weighing nearly thirty pounds—all are seen here, on a scale which seems to rank midway between that of a common smithery and of an anchor-smith's shop. A separate shop is usually devoted to the casting of such articles as are formed of cast-metal, and to the cutting, turning, &c. of others in which neatness of appearance is required; these shops are smoky and hot, a necessary result of the operations carried on there.

Near to or connected with the smithery is generally an ironmonger's store-room, supplied with all kinds of ironmongery for the use of the yard. For the use of these large establishments, not only bolts, nails, screws, &c. are kept, but also tools, such as saws, axes, adzes, hammers, augers, shovels, &c.

Every ship-yard has got one or more 'building-slips,' which are occupied in the following manner:—When a ship is about to be built, it is necessary to select a spot of ground from whence the vessel, when finished, may be readily passed into the water. For this purpose, a sloping tract of ground is dug or prepared, larger than the full dimensions of a ship, and at right angles to the river.

This channel is level with the ground at the upper end, but is several feet beneath that level at the lower end, and open to the water. On this inclined slip of ground a ship is built; and at a certain stage in the progress, the gates, which had shut out the water from below, are opened, and the ship launched into the river. A 'dry-dock' is made in a different way, and for a somewhat different purpose. It is an excavation entirely below the level of the ground from end to end, slightly inclined towards the river, and open to it at the lower end, where folding gates shut off the communication when required. Docks of this kind are not employed for building ships, but for repairing them; and the arrangements for docking are as follow:—When a ship is about to be brought into dock, a row of blocks are laid along the bottom of the dock; and the gates are opened at or about the time of low water. As the tide rises, it flows into the dock to the same level as the river; and when there is a sufficiency of water in the dock, the ship is floated into it, and guided as nearly as can be into the centre. While the tide is going down again, the water flows gradually out of the dock, and the ship sinks deeper in consequence; so that by the time low-water has again arrived, the dock is nearly emptied of water, and the keel of the vessel rests on the blocks beneath. In the mean time preparations have been making for securing the ship in her proper position, by shores, ropes, &c., so that she shall stand vertically on her keel; and at or about low-water the gates are shut, not again to be opened until the repairs of the vessel are finished. In this way a ship is dry-docked, and workmen can then descend into the dock, and examine every part of the ship's bottom down to the keel.

Numerous other buildings always form part of the general assemblage: such as wet-docks, timber-stores, saw-pits, converting-sheds, boat-sheds, mast and block makers' shops, &c. The bending of the timber requires the aid of a steaming-house, where planks are steamed preparatory to being laid outside the timbers of a ship; the steaming is effected in square wooden trunks, about thirty feet long, provided with iron doors at one end, which are lifted up by balance weights, and on the opening of which planks are slid into the trunks, to be afterwards exposed to the action of steam.

Let us now rapidly trace the manufacturing operations. In the first place we will suppose that a merchant orders a ship, intended for a particular line and kind of traffic, to be built by a ship-builder. The mode of measurement, by which an agreement is made between the parties, is rather singular, and is by no means easily understood by those who are not familiar with the general details of shipping. It is by *tonnage*, and is supposed to represent the number of tons of cargo which the proposed vessel will carry. Tonnage is estimated sometimes by bulk, but more generally by weight; a ton by bulk being equal to forty cubic feet; and a ton by weight equalling twenty hundredweights. There are certain formulæ employed by ship-builders, whereby the tonnage is calculated from the length, breadth, and depth of the vessel; but these formulæ seldom give the real tonnage, that is, the real amount of cargo which the vessel will carry; because two vessels exactly equal in length, breadth, and depth —measured as those dimensions usually are—may have very different internal capacity, owing to different curvatures of the hull. A ship will sometimes carry more cargo than her 'tonnage' indicates; sometimes less; and therefore the word tonnage is to be regarded only as a rough approximation to the burden which the vessel will carry.

Still, however, the 'tonnage' is always one of the items of agreement between the builder and the owner, partly from the circumstance that when a vessel is registered, the tonnage is made to indicate its rank or class. In addition to this, the dimensions of the vessel about to be built are agreed upon, as well as the thickness and quality of the more important timbers, the thickness of the planks laid on the outside of the timbers, and other details of a more minute kind.

The specification of the vessel being thus drawn up, the ship-draftsman commences his labours, which are of a parallel nature to those of an architect in common building. He prepares drawings of the vessel in various points of view, so as to represent the dimensions not only of the vessel itself, but also of the principal timbers composing it, and also the curvatures of those timbers.

The draftsman having prepared these working drawings, generally on a scale of about a quarter of an inch to the foot, the next thing is to prepare a working *mould* of the ship, as large as the ship itself, in the mould-loft. The mould-loft floor is in most instances large enough to receive half the length of the intended vessel, with the whole height; and on this floor the draftsman chalks a large number of lines, derived from the working drawings, but enlarged to the full dimensions of the vessel. These lines, generally speaking, represent the exact dimensions and curvatures of the timbers required to form the vessel; and when all the lines necessary for one-half the length of the vessel are laid down, say the bow end, another series is then laid down, on the same floor, for the stern end; the two series intersecting and mingling among each other in every part. Practice enables the draftsman to distinguish one series from another, and thus obviate the necessity of having a mould-loft floor equal to the length of a large ship. When these lines, which amount to a large number, and present nothing but a confused assemblage to the eye of a stranger, are laid down, thin pieces of American deal, about three-quarters of an inch in thickness, are cut and adjusted to the curvatures of the lines, different pieces being joined end to end to produce the requisite lengths. These pieces of deal, which are called *moulds*, assist the sawyers in cutting the oak to the required sizes and curvatures for the different timbers of a ship; and there are certain marks on each piece which further this object. Let us suppose that one of the curved timbers is to be twelve feet in length, one foot thick, one foot wide, and so tortuous in form that its curvature is not circular, and none of its angles are right angles; in such case the piece of pine which forms the mould will give the curvature of the timber, while certain marks on its surface indicate the places where bevellings and angles are to be made from directions given on another board. On these principles the construction of the moulds proceeds, until a sufficient number of pieces is prepared to guide the sawyer in cutting all the timbers of the ship. For a large East Indiaman the number of moulding-pieces thus required is more than a hundred, each of which is marked and numbered in various ways.

The mould of the ship being thus prepared, the next operation is to cut up the oak and elm trunks to the proper dimensions for the various parts of the ship. This is called 'converting,' and is a process requiring great art and judgment; for the wood must be selected not only with a view to avoid waste, but also that the grain of the wood, in preparing a curved timber, may be cut crosswise as little as possible, since such a mode of cutting would greatly weaken the timber. It is, therefore, desirable that a crooked trunk be selected for preparing a curved timber, and that the crookedness of the one correspond as nearly as may be with the curvature of the other. The superintendence of this department is in a person possessing much experience and knowledge of the quality of different woods, and of their relative fitness for the several timbers of a ship. When this superintendant or 'converter' has selected the proper wood, the operation of sawing proceeds nearly as in a common sawpit. The trunk of the tree is laid across a framework in the usual manner, and two men, one above and the other below, cut the wood by means of a long saw. The thin deal mould is use as a constant guide in cutting; the curvature, the breadth, the thickness, and the angles, all being regulated by the mould itself or by the marks and directions chalked or painted on it. In a place where so much timber is used as in a ship-building yard, it might at first thought be imagined that machine-worked saws would be used; but the curvatures and angles of the timbers are so extremely varied, not only in different timbers, but also in different parts of the same timber, that the precision and regularity of machinery would be here thrown away, and indeed unavailable.

So far, then, we may suppose the principal timbers to be cut. This operation is effected in sawpits covered by sheds. As the timbers are wanted they are conveyed to the building-slip, or that spot of ground on which the construction of the ship takes place. When the timbers are thus removed, they pass from the control of the 'converter' to that of another superintendant or foreman, who is the ship-builder or shipwright properly so called.

The building-slip is prepared for the operations in the following manner:—The ground having been cleared and made tolerably clean, a row of blocks is laid down from end to end of the ship, the length of the blocks being transverse to or across the slip. The blocks are of oak, placed one upon another, to the height of three or four feet, and secured together. These piles of blocks are ranged along the slip, at distances of five or six feet apart, and the upper surfaces of all the blocks are so adjusted that they shall be in one straight line, but inclining slightly downwards towards the river, the inclination being about five-eighths of an inch to a foot of length. Great care is taken in laying down these blocks, as they form the support,—the workbench, in fact,—on which the whole ship is afterwards built, the keel being laid down immediately upon the blocks.

In order to understand the succession in which the parts of a ship are put together, it is useful to notice certain points of comparison between a ship and the human skeleton. The keel is the backbone of a ship, and the frame-timbers are the ribs; the ribs forming an arched exterior to the whole of the body or hull, and the keel forming the longitudinal column to which the ribs or timbers are attached. The keel is, therefore, the principal part of the vessel, and the one above all others whose strength and security are indispensable to the safety of the vessel. From this circumstance, and from the position of the keel at the lowest part of the vessel, it constitutes the first part of a ship laid down on the slip. The keel is made of elm, and is of such length, except in small vessels, that no single tree will form it; and, therefore, two or more pieces are joined together, or, as it is termed, *scarfed*, end to end, until the required length is produced. This scarfing is a kind of overlapping, the under part of one piece and the upper part of the other, or the right side of one and the left side of the other, being cut away near the ends, and the cut or scarfed surfaces bolted together. For an East Indiaman of a thousand tons burden, the keel is about a hundred and forty feet long, fourteen inches wide, and fifteen deep. For a steamer of the same burden the length is several feet greater, since steamers are generally longer and narrower than sailing vessels of equal burden.

The sides and the ends of the keel are grooved and cut in various ways, to receive the different timbers and pieces of wood forming the hull of the vessel. Of these timbers two, which form the main supports of the two ends of the vessel, are the *stem* and the *sternpost*, of which the former curves upwards from the higher end of the keel, and the latter rises almost perpendicularly from the lower end (for a ship is built with the stern-end towards the river, and is consequently launched stern foremost). Both are formed of oak, and are attached to the ends of the keel in a very substantial manner. To the sternpost are attached various pieces of wood, called transoms, fashion-pieces, &c., the contour of which, when fixed in their places, is such as to give the elegantly curved form to the hinder part of the vessel; while to the stem are attached various pieces, some of which fit it more securely to the keel, some serve to connect it with the timbers and planks afterwards to form the sides of the vessel, and others form a receptacle or support for the end of the bowsprit. The heavy pieces of timber erected thus on the two ends of the keel are hauled up to their proper positions by pulleys and tackle, and then shored up by poles from the ground, to prevent them from sinking.

Along the keel, nearly from end to end, are fixed stout timbers, called *floor-timbers*, at right angles with the length of the keel, and slightly concave on their upper surface. They are placed a few inches apart, and constitute, as the name imports, the floor of the ship. As there is a general upward curvature of the ship towards each end, the floor rises in a similar manner, and would thus leave a vacancy between the end floor-timbers and the keel, but this vacancy is filled up with solid wood, called *dead-wood*, constituting a firm foundation. The floor-timbers may be regarded as the lower part of the ribs of the ship; and above them spring up the various pieces forming the remainder or vertical part of the ribs. No wood can be found so large, so curved, or so strong as to form the whole curved rib; and, therefore, each rib is built up of separate pieces, the general name of which is *futtocks*; thus we have the first, second, third, and perhaps fourth futtock, each being a distinct piece of timber, but all collectively forming one rib, or one 'frame of timbers.' These pieces are placed, some end to end, and others side to side, in such a manner that the joint of two ends of timber may have a support of solid timber at its side. Various means are adopted for joining the pieces end to end, but those which are placed side by side are bolted together with bolts.

As the various futtocks curve more and more upwards, till the upper one, or 'top timber,' reaches to the top of the hull of the ship, it must be evident that all the pieces forming one rib or 'frame of timbers' are very ponderous, especially if the vessel be large. The arrangements, therefore, are regulated according to the dimensions of the vessel. If it be large, the pieces, after being fitted together on the ground, are raised up singly, or perhaps two bolted together; but if it be small, three or four pieces may be bolted together on the ground, and raised as one piece. But in whatever way this part of the matter be arranged, the other operations are nearly alike. All the pieces to form one rib are adjusted and fitted to each other on the ground, and are lifted from the ground by strong tackle. The curvature and weight of the pieces is such, that after being raised and adjusted to their places they must be secured from falling either inwards or outwards; for the former of which purposes planks called *cross-spalls* are nailed to the upper ends of the timbers, at right angles to the keel, and stretching across from one side to the other; and for the latter, planks called *rib-bands* are placed nearly horizontal round the outside of the ribs at various heights, and are shored up by poles fixed in the ground beneath.

In this manner the ribs or frames of timbers are raised one after another, from end to end of the vessel, the two halves of each frame, that is, the two parts springing from opposite sides of the keel, being raised nearly at the same time, so as to maintain the top timbers at the proper breadth across the vessel. In this stage of the proceedings, the interior shell of the vessel presents a singular scaffold-like appearance. At the bottom, just above the keel, are the floor-timbers, ranged at right angles to it, and projecting some distance beyond it on either side; at the ends of these timbers are the various pieces or futtocks forming the ribs, jointed and bolted together at different parts of their heights; the ribs rise to different and irregular heights, afterwards to be adjusted; and across, from the upper part of the timbers on one side to the upper part on the other, are the spalls, the temporary wooden braces which keep the opposite sides at their proper distances.

The form of the hull is thus given; in a rude manner, it is true, but still with a degree of certainty which determines the character of the vessel. The numerous pieces subsequently added, whether of British or African oak, elm, or fir, are sawn at the pits, under the supervision of the 'converter;' and are afterwards, in most cases, trimmed, or, as it is termed, 'dubbed,' with an adze. In common carpenter's work, the only tool used, after the saw, for paring away and levelling the surface of wood, is generally the *plane;* but in the work of the shipwright, where more bulky materials are operated on, where almost every piece is to be hollowed or rounded in some part or other, and where great neatness is not required, the adze becomes a valuable instrument. The various kinds of joints whereby one timber or plank is connected with another, such as tenon-and-mortice, &c., are made by the aid of nearly the same tools as those employed in carpentry, but of a large size and stronger make.

The keel, the sternpost, and the stem form the three great supports of the frame of the vessel; the first being horizontal, the second rising from it almost perpendicularly at one end, and the third rising in a curve at the other. Among the timbers which are subsequently adjusted to the vessel are three, called the keelson, the sternson, and the stemson, which are in some sense interior representatives of the three just named. The keelson is fixed on the floor-timbers, immediately over the keel, and forms that part on which the steps or blocks of wood are placed which support the masts: it is secured down to the keel by means of bolts three feet in length, which pass entirely through both, as well as the intervening wood. The stemson and the sternson rise from the two ends of the keelson, and form internal supports to the ends of the vessel. The timbers are often strengthened within by pieces called *riders;* but in modern vessels they are frequently secured and braced one to another by diagonal iron plates, from half an inch to an inch in thickness, passing nearly from the top to the bottom of the hull, inside the vessel. Being bent round the concavity of the ship's side in an oblique direction, each piece of iron crosses several different frames of timbers, and is securely bolted to them all.

The small portion of the hull of a vessel which is seen above the level of the water presents to view a surface covered with horizontal or nearly horizontal ranges of planking; and if we could see lower down, towards the keel, we should find a similar approach to a horizontal direction in the pieces of wood with which the hull is covered. Withinside, too, a similar arrangement is observable. The vertical frames of timbers of which we have been speaking do not present themselves to the eye of a person viewing a finished vessel, either within or without. The whole are covered with planking, laid in nearly horizontal rows or 'strakes.' The planks may be regarded as forming the skin with which the ribs of the ship are covered; and, indeed, the shipwrights, who almost seem to regard their ship as a living being, apply the term 'skinning' to the operation of laying on these planks; an opposite sense, it is true, to that in which we are in the habit of using this term. Nor is this skin by any means a trifling affair, for the thickness of the planks which form it varies from about three to six inches. The planks are formed of sound durable oak, and are often nearly thirty feet in length. They are brought, while at the sawpit, as nearly to the required form as may be practicable; and are afterwards worked with the adze, to give them the proper contour. This must not be supposed to imply that the planks are hollowed or curved by the adze to the exact shape of the vessel, but that the width and thickness of adjoining planks are adjusted to each other. When a prepared plank is laid against the outside of a vessel, the convexity of the latter causes the ends of the planks to stand out several inches from it; and, on the other hand, when laid on the inside, the concave surface causes the ends to be in contact with the timbers, and the middle to be several inches away from them. The planks require, therefore, the aid of powerful instruments to force them close to the timbers previous to bolting, and this operation is further assisted by bringing the plank to a heated and moistened state by steam.

The parts of the planking vary in thickness, and receive distinctive names, according to the places which they occupy: but all are treated nearly in the same way —sawn, dressed with an adze, steamed, forced to the curvature of the ship, and fastened to the timbers with bolts. The trenails, which are more numerous than the bolts, are not driven in till a subsequent stage in the operations. In adjusting the planks to the ship's sides, care is always taken that the adjoining ends of two planks in one row or strake shall not occur at the same part of the ship's length as a joint in the row next above or below it, a caution similar to that observed in laying the courses of bricks in a wall, or the rows of slates on a roof, and the object of which is sufficiently obvious in relation to the strength of the structure. Whoever has an opportunity of seeing the whole hull of a vessel, will observe that the planking is ranged with great regularity, each strake or row diminishing in width towards the ends, to conform with the diminishing size of the vessel.

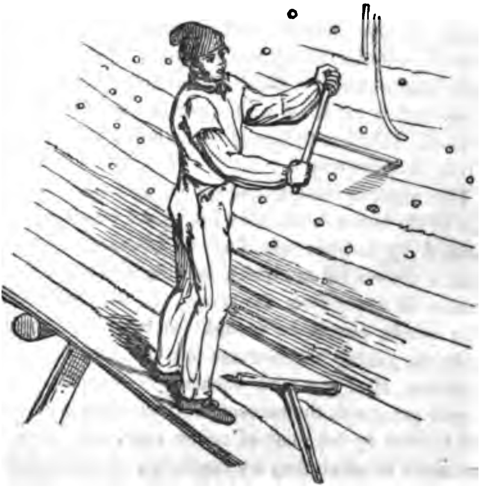
In the building of a ship matters are so arranged that many different parts are in progress simultaneously ; some workmen making preparations for the beams of a vessel withinside, while others are planking the exterior, and others perhaps engaged at various parts of the head and stern. The beams are stout and well finished timbers stretching across the vessel from side to side, at intervals of a few feet, and serving not only to support the deck or decks, but also to bind the two sides of the vessel together. These beams, situated as they are at right angles to the keel, have given rise to many nautical expressions which are rather incomprehensible to general readers: thus the 'breadth of beam' is the width of a vessel; an object seen at sea in a direction at right angles with the keel, is said to be 'on the beam;' when a ship inclines very much on one side, so that her beams approach to a vertical position, she is said to be on 'her beam ends;' and many other similar phrases might be adduced.

The beams are ranged at such distance apart, that an East Indiaman of a thousand tons burden requires about thirty beneath the main deck. Each beam is usually formed either of one or of three pieces, according to the dimensions of the vessel ; the three pieces, in the latter case, being securely joined or scarfed together. The beams are not straight, but are curved upwards in the middle, so that their upper surfaces are convex and their lower concave ; the bending being such that there is a curvature of about one inch to every yard in the length of the beam. The ends of the beams are made to rest on stout planks called clamps; but the real fastening is by means of iron brackets technically termed *knees*, bolted both to the beam and to the timbers of the ship. Besides the fastenings at the two ends of each beam, there are supporters in the middle, which are often formed of cast-iron, combining lightness of appearance with strength.

Various ledges and frames, called *partners*, *coamings*, and *carlings*, being arranged between the beams, the decks are next attended to. These divide the hull into different stories, analogous to those of a house; and in the one case as in the other, the number of floors is greater in some instances than in others. Large ships of war are furnished with three entire decks, reaching from the stem to the stern; besides two shorter decks called the forecastle and the quarter-deck, the one placed at the head of the vessel, and the other towards the stern, a vacant space called the *waist* being left between them, at the middle of the ship's length. In smaller vessels of war, and in merchantmen, the decks are fewer; two whole decks and a quarter-deck being the number in an East Indiaman. The deck is generally made of Dantzig or Memel fir, and for vessels exposed to a hot climate yellow pine is sometimes employed. The deck planks are laid side by side, lengthwise of the ship, or parallel to the keel, and vary from six to ten inches in breadth, and from two to four in thickness. They are nailed down to every beam and to every carling, either with iron nails or with nails formed of a mixed metal.

We have said that the planking which covers the inside and outside of a ship is secured, partly by bolts and partly by wooden pins called trenails, to the timbers;

and that the trenails are not driven in until some time after the bolts. The object of this seems to be, that by making the trenail-holes a considerable time before the trenails are inserted, the wood round each hole has an opportunity to become seasoned. The holes are made with an auger, which is a kind of gimlet or borer, varying from an inch to two inches in diameter, according to the size of the trenail to be inserted. The head of the auger is provided with a cross handle of considerable length, which furnishes a leverage to the workman using the instrument. This kind of labour is often very severe, from the hardness of the wood, the great depth to which the hole is to be bored, and the awkward position in which the man has to place himself. The curvature of a



ship near the keel is almost horizontal, and at other parts goes through all the gradations from a horizontal to a vertical direction: and the man who is engaged in boring the trenail-holes has to vary his position and mode of working, sometimes standing and at other times sitting, according to the part of the vessel at which he is at work. It is so arranged that the same trenail shall pass, not only through the outer planking and the frame-timber, but also through the inner planking; by which all three are bound well together; and the trenail-holes are bored in conformity with this arrangement. When the proper time arrives for driving in the trenails, a set of men, each provided with a large and heavy hammer, proceed to that operation. The trenail is made slightly larger than the hole into which it is to be driven, so as to bite or cling closely to the timbers; and a succession of powerful blows is requisite to urge it forward. The trenail is a little longer than the depth of the hole, and the superfluous end is taken off with a saw when the driving is finished. It is then tightened in the hole by small wedges driven in at the end.

The planking and trenailing having brought the surface of the hull to a tolerably even state, which is further assisted by a little trimming or 'dubbing' with the adze, a process follows which is indispensable to the exclusion of water from the vessel, viz. that of *caulking*. The planks cannot be brought so close together as to make the joining impenetrable to water, and the joint is therefore filled up with oakum. We explained in a former paragraph the manner in which threads of oakum are twisted by boys out of refuse rope, and alluded to the mode in which they are employed. A kind of chisel, called a caulking-iron, is employed to drive the threads of oakum into the seams. The oakum is not placed merely at the outer edges of the crevices, but is driven in to a depth equal to the whole thickness of the plank. Sometimes the edges of the planks are chiselled away a little, in order to afford room for the entrance of the oakum; and in all cases the caulkers manage the seams in such a manner as to fill them up with a dense and compact layer of oakum, which not only answers the purpose of making the vessel tight, but also helps to consolidate and strengthen the whole ship in a very considerable degree, by making the edges of the planks bear hard against each other, so that one part cannot move or work independent of another. At the time when this caulking of

the seams is going on, the planks themselves are examined, and any shakes or rents or fissures, however small, are well filled with oakum. This process being finally completed, all the caulked seams are coated, or, as it is termed, 'payed,' with hot melted pitch and rosin, by which the hempen fibres of oakum are preserved from the action of the sea-water. The *sheathing* is an exterior coating afterwards put on the bottom of the vessel; but this is a stage in the proceedings at which we have not yet arrived.

The operations withinside the vessel are, as may be supposed, much more varied than those on the outside, but they partake more and more of the nature of carpentry as the construction of the vessel advances. After the various pieces are adjusted which form the main support of the different parts of the vessel, the hull is divided into compartments accordant with the purposes for which the vessel is intended. The decks, port-holes, magazines, and berths for several hundred men in a man-of-war, and the cabins, the passenger accommodation, and luggage-room of a merchant ship, of course require different arrangements of the interior. Supposing these matters to have been completed, we will next proceed to the important affair of *launching*, by which the vessel is borne on to the liquid element which is afterwards to form her home. Those persons who have never seen a ship launched, and who are but little acquainted with these matters, may feel it desirable to know in what stage of the building process the launching is effected. We may here mention, then, that the hull is launched before it has been sheathed or coated with copper, and also before it is fitted with masts, yards, bowsprit, rudder, sails, or ropes. There are various reasons why these several parts are more conveniently fitted after than before the launching; the height of the vessel from the ground when on the building-slip—the angle at which it slopes towards the water—the difficulty of getting into the vessel, &c., are some of these reasons; and with regard to the sheathing, it is deemed better to be postponed until the soundness of the naked planking has been tested by immersion in the water.

We explained in a former paragraph, that the ship is built on blocks, laid in regular succession along the building-slip, and so adjusted that the keel, which rests immediately on their upper surfaces, shall have an inclination of about five-eighths of an inch to the foot towards the river. These blocks form the central support beneath the vessel, during the whole progress of building; and the vessel is further supported at the sides by shores, or poles, raised at various angles from the ground. As the time of launching approaches, preparations are made for removing all these lateral supports, for lifting the keel completely from the blocks, and for constructing two temporary 'slippery paths' down which the vessel may slide into the river. The whole of these operations are very curious, and require great nicety and care to ensure success. Along the building-slip, on each side of the keel, and distant from it about one-sixth of the vessel's breadth, is laid an inclined platform, formed of many pieces of wood, and presenting a flat upper surface inclining downwards towards the river at an angle of about seven-eighths of an inch to the foot, and consequently more sloping than the position of the keel. The inclined plane thus formed is called the 'sliding-plank;' and it has a raised edge, or ledge, called the 'side-way,' or 'riband,' projecting four or five inches upwards from its outer edge. The sliding-plank is placed upon supporting blocks, so as to be elevated some feet from the ground. A long timber called a 'bilge-way,' with a smooth under-surface, is laid upon this sliding-plank; and upon this timber, as a base, is erected a framework, reaching up to the hull of the ship. This framework, which is called the 'cradle,' is formed partly of solid woodwork, filling up the whole space between the bilge-way and the hull, and partly of short poles called 'proppets,' which are erected nearly vertically, and abut against a plank fastened temporarily to the bottom of the ship. These operations are carried on on both sides of the keel, and at a few feet distant from it; and the vessel may in this state be almost said to have three keels, the real one midway between two temporary ones. At a certain stage in the building-up of these pieces, a layer of tallow, soap, and oil is placed between the sliding-plank and the bilge-way, to diminish the friction during the sliding of the latter.

But it is not sufficient that these two temporary false keels reach up to the hull: the hull must actually bear with its whole pressure upon them, so that the blocks beneath the real keel may be relieved from the enormous weight of the vessel. To effect this, a great number of wedges are driven in just above the bilge-way, by the action of which the vessel is in some degree lifted off the blocks, and made to rest on the bilge-ways. This operation is one of the most singular which a ship-yard presents. Very frequently a hundred men are driving the wedges at once; half of them being ranged on one side of the vessel and half on the other. Each man is provided with a heavy hammer, and at a given signal all strike together, whereby a hundred wedges are driven at the same instant. The effect produced by the wedge is at all times one of a remarkable and powerful kind; and when the exertions of so many men are in this manner simultaneously applied, the effect is irresistible: the huge ship, though not actually elevated above the central blocks, is so far moved as to transfer her pressure from them to the bilge-ways and sliding-planks. If the shores by which the sides of the ship are supported were now knocked away, the vessel would be likely to slide down into the river, the bilge-ways gliding over the slippery surfaces of the sliding-planks. But to prevent this from occurring before the proper time, a short piece of wood called a 'dog-shore' is fitted to the upper end of each bilge-way, in such a manner as to prevent the bilge-way from beginning to slide so long as the dog-shore remains there.

A few other arrangements being made, the ship is ready for launching. The dog-shores, and the hammers with which they are to be knocked away, are generally painted blue, and now become conspicuous objects, for a visitor looks at them as the apparently slight means whereby the vessel is to be urged into the water. A screw is fixed against this end of the keel, to assist in urging the ship forward, if such a course be necessary, and some of the blocks under the keel are cut away, to make the vessel rest more entirely on the bilge-ways.

At a given signal two men, one on each side, knock away the dog-shores; the vessel glides slowly downwards into the water; a flask of wine is thrown at the head; she is christened with the name selected for her; and when she touches the water all give her a hearty greeting. This is an exhilarating sight, and has formed the subject for many a picture and many a description.

## CHAPTER VII.

### MAST-MAKING; SHEATHING; SAIL-MAKING.

Having thus traced the history of a ship up to the period of launching, we will in this chapter speak of the modes of making and fitting the masts, the sheathing, and the sails. Whether the masts are placed in the vessel immediately after she is launched, or whether some other operations are previously performed, depends on many different circumstances; but in either case, the masts have been prepared during the time that the ship has been on the stocks, the workmen employed on the one being a totally different set from those engaged on the other, and the operations being carried on in a different part of the yard. Masts, as is well known, serve as supports to the sails, and are themselves supported by ropes and tackle. The number varies in different kinds of ships; for instance, a ship properly so called is provided with three masts; a brig and a schooner each provided with two; while one mast forms the complement for a sloop, a cutter, or a smack. But it is necessary here to remark, that a mast is not, except in small vessels, a straight piece of timber put up in one single length: it is generally formed of three stages or tiers rising one above another, each of which receives a distinctive name. Let us take for example a 74-gun ship of war. Here are three masts, the foremast, the mainmast, and the mizen-mast; and each one of these three is formed of three subordinate masts, rising one above another, of which the lowest is termed the lower mast, the next in height the topmast, and the third the topgallant-mast. The length of the lowest is rather more than that of the other two put together; and the united length of the whole is, in the case of the mainmast, above two hundred feet. In a merchant vessel, say of a thousand tons burden, the arrangement is just the same in principle, but the dimensions smaller, the nine subordinate masts varying from about twenty to ninety feet in length, the shortest being the mizen topgallant-mast, and the longest the lower mainmast.

The masts for large merchant ships vary from about ten to twenty-eight or thirty inches in diameter; and as the latter dimensions are too great to allow the whole to be made from one tree, the mast is built up of several pieces, laid side by side in various ways, and bearing the technical names of spindles, side-trees, front-fishes, side-fishes, cheeks, cant-pieces, fillings, heel-pieces, and others equally unintelligible to general readers. The principal part of each mast, or the whole mast, if the diameter be small, is made of Canadian fir, a tree which presents a remarkably straight and uniform trunk

A mast-making shop is generally a very large roofed building, above a hundred feet in length, and situated near a mast-pond, so that the masts can be floated in or out of the yard with great facility. The mast-makers have some tools peculiar to themselves; but the main operations bear some resemblance to those by which the timbers of a ship are fashioned. The various pieces of which a mast is built up are sawn to their proper dimensions, and fitted together by various kinds of joints, called coaking, dowelling, &c., and of which the common tenon and mortice will furnish some idea. Various cutting instruments are employed to give the rounded or convex form to the mast, when the pieces are put together; and pieces of wood are attached to its surface, to answer several purposes, when the mast is put in its place in the ship. The extent to which this building-up of a mast goes may be judged from the fact that the lower mainmast alone of an East Indiaman weighs upwards of six tons; and when lying along the floor of the mast-shop, its length of ninety feet and thickness of two and a half impress one with no mean idea of its bulk.

The various pieces of which a large mast is formed would not be permanently retained in their proper places, were there not some external band or tie employed. The band used for this purpose consists of a series of iron hoops, ranged at intervals of four or five feet apart along the mast. These hoops are formed of iron bands about three inches in width and three-eighths of an inch in thickness; and after being welded as nearly as may be to the girth of the mast, they are fixed on it. Each hoop—of which the lower mainmast contains about twenty, and the others a proportionate number—is in the first place heated, not to such a degree as would scorch the wood on which it is laid, but so far as to give a slight expansion to its dimensions. A small brick-built kiln is situated near the mast-shop, and in this kiln a fire is made, on which the iron hoop is laid to be heated. When the heating is effected, the hoop is taken up by means of a kind of tongs, carried to the mast-shop, put over the small end of the mast (for every mast is of smaller dimensions at one end than the other), and pushed on as far as its diameter will permit. A party of fourteen men then join their exertions to drive the hoop on as tightly as possible. Six of them grasp a long iron bar called a 'poker,' and stand in an oblique line on one side of the mast; six others hold a similar bar on the other side of the mast; and the remaining two are provided with heavy hammers. The men, thus placed, then strike the hoop with the two pokers, the end of each poker being made to strike against the edge of the hoop, and all the twelve men urging the two pokers simultaneously, by which very powerful blows are given. At the call of 'hands up,' the men direct their blows to the edge of the upper part of the hoop; while 'hands down' is a direction to them to make the blows lower down. The two men with the hammers meanwhile deal powerful blows on the surface or face of the hoop. As the hoop is driven onwards to a thicker part of the mast, it necessarily binds the wood more tightly, and this is still further effected by the contraction of the hoop as the iron becomes cold. The ultimate effect is that the hoops give an extraordinary degree of strength to the mast.

The *bowsprit* and the *yards* of a vessel are made by the mast-makers, and may indeed be considered as masts, so far as the mode of making is concerned. The bowsprit is a large mast which projects obliquely over the stem, to carry sail forward, in order to govern the fore part of a ship, and to counteract the force of the after-sails; it also serves to hold the stays or ropes by which the foremast is kept in its position. It generally rises at an angle of about thirty-six degrees. It very nearly equals in diameter and is about two-thirds of the length of the lower mainmast; being, in an East Indiaman, nearly sixty feet in length, and two and a half in diameter at the larger end. The *yards* are long pieces of timber suspended upon the masts, for the purpose of extending the sails; some being suspended across the masts at right angles, and called square yards; others suspended obliquely, and termed lateen yards. The number of these yards in a large ship is about twenty, and the dimensions of some of them are very considerable. The main yard of a first rate man-of-war is above a hundred feet in length and two feet in diameter; while the other remaining yards have various lengths down to about twenty feet, and various diameters down to three or four inches.

In fitting the masts, the great difficulty is to get in the three lower masts; for the upper ones are afterwards drawn up by means of tackle with comparative ease. The lower masts are fitted in three different ways, viz. by *sheers*, by a *sheer-hulk*, or by a *masting-house*.

The *sheers* used in masting vessels are two large poles, masts, or spars, erected on the vessel whose masts are to be fixed; the lower ends resting on thick planks laid along the sides of the deck, and the upper ends crossing each other, where they are securely lashed. The point where the two spars cross is exactly over the hole where the mast is to be dropped through the deck; and the spars are retained in this position by strong ropes attached to different parts of the ship. The mast, being floated to the side of the ship, is elevated entirely above deck by means of tackle connected with the sheers; and when it is brought with the lower end immediately over the hole in the deck, it is gently lowered into its place, passing down through the entire height of the vessel, and resting on the step or block fixed to the keelson. When one of the three masts is fixed in this way, the sheers are moved to the spot where the second is to be placed, and afterwards to the third. This is the general mode of masting merchant ships.

The *sheer-hulk* is an old man-of-war cut down to the lower deck, and fitted with an apparatus of sheers, tackle, &c. for masting the ships of the royal navy. There is a mast, a hundred and twenty feet in length, fixed in the hulk, and acting as a support to three or four stout spars or sheers which project obliquely from the side of the vessel. The tops of these sheers are at such a height and project to such a distance from the side of the hulk, that the vessel which is to be masted can come beneath them, and be fitted with her lower masts, which are hoisted up to the requisite height by the sheers, and then lowered into the vessel. This is the general mode of masting ships of war.

The *masting-house* is a building erected expressly for the operation of masting ships. We are not aware whether there are others of the kind in this country; but the one at Blackwall, formerly belonging to Mr. Perry, and now in the possession of the East India Dock Company, is the place at which many of the Thames-built ships are masted. It is a square wooden building, erected on the western quay of the outward-bound dock, and having at the top a platform overhanging the water to the distance of several feet. The ship to be masted is floated into this dock from the Thames, and brought immediately beneath the overhanging platform. The masts are likewise floated in; and, after being hoisted up one by one by means of tackle connected with the platform, lowered into their proper places in the ship.

Having thus spoken of the masting of a vessel (by which is usually understood the lower masts only), we will follow it back to the building-yard. The difference between a building-slip and a dry-dock, and the manner in which a ship is brought into the latter, have been before explained; and we will suppose a vessel therefore to have been dry-docked, and to be ready for the process of *sheathing*, which is frequently done about this stage of the proceedings. The planks with which the timbers of a ship are covered, although the seams may be caulked with oakum and pitched, are not in a condition to be exposed to the sea without serious injury; and a casing or sheathing is therefore applied. Deal or fir plank, sheet lead, brown paper coated with tar, and sheet copper, are the substances which have been employed for this purpose; and experience has shown the last to be the best. Formerly so much grass, ooze, shells, sea-weed, &c. accumulated on and adhered to the bottom of a ship during a voyage, that the speed was impaired; and a process of breaming or graving was frequently required when she was in dock. This breaming consisted in melting the pitchy coating with which the bottom was covered, by holding kindled furze, faggots, or reeds under it, and thus loosening the matters which adhered to it, and which were subsequently scraped and brushed off. With the hope of rendering this process less frequently necessary, a sheathing of copper was proposed about eighty years ago; and the result was so satisfactory, that in

1783 the government ordered all ships belonging to the royal navy to be copper-bottomed. The practice spread from thence to the mercantile marine, and is now very generally followed.

The sheets of copper, or of an alloy of copper and zinc, for sheathing, are about four feet long by fourteen inches wide; the thickness being such that one square foot weighs from sixteen to thirty-two ounces, generally from twenty to twenty-eight. The copper is sometimes laid on the bare planking, but in other instances there is an interposed layer of paper, of felt, or of sheathing-board. The two latter are nailed on in their usual state; but if paper be employed, the sheets are first dipped in a mixture of melted tar and pitch, left to dry, and then nailed on. But whether these interposed layers are used or not, the copper sheets are put on in a pretty uniform plan. The sheets are pierced with holes, not only all round the edges, but at intervals of three or four inches over the whole surface. Each *sheet laps* about one inch over the adjoining sheet, and is fastened to the ship by means of flat-headed nails, made of the same metal as the sheets. Great regularity is observed in the arrangement of the sheets, so that a certain symmetry of appearance, as well as a durability, is attained.

The number of sheets of copper required for a large ship is very considerable. Nearly eight thousand square feet are required for an East Indiaman of a thousand tons burden. After two voyages to the East Indies, the coppering requires to be renewed; and the old copper is found to have lost three or four ounces of its weight in the square foot, by the action of sea-water, friction, and other causes. For re-coppering a vessel, the ship is docked, and stages or platforms built round her hull, on which the workmen may stand. With instruments adapted to the purpose, the men then strip the old copper from the ship's bottom; and it is sent away to the copper-works to be again melted up into a useful form. The surface of the planking being brought tolerably smooth, and prepared in one or other of the ways alluded to above, the nailing on of the sheets of copper proceeds in the same way as for a new vessel. In a large ship-yard where many hands are employed, and the general arrangements are on a complete scale, a vessel is frequently sent out of dock thoroughly new-coppered within two days of the time when she entered it.

We may next speak of the manufacture of the *sails* of a ship. Sail-cloth is the stoutest, the strongest, and the most durable of all varieties of *flax* fabrics. It is in fact a *linen*, so far as linen is a generic name for woven flax; but *canvas* is a more usual name. The powerful strain which the sails of a large ship are required to bear, renders necessary the employment of well-spun flax and well-woven yarns in the production of the cloth from whence they are made. In the Royal Dockyards the quality of the sail-cloth is closely attended to; and there is equal attention paid to the subject in the East India Company's shipping. In the merchant service generally, the quality is more or less excellent, according to circumstances; and any one who has glanced at the shipping below London Bridge will not fail to have remarked the strange medley of sails which the lower classes of vessels display.

Why it is that sails are not made of *broad* canvas, of a width somewhat analogous to that now employed by the and machines of an ingenious kind are employed in supplying these quills with yarn. In the old-fashioned process of hand-weaving the quills are filled by women or children, who use a simple wheel to wind the yarn on them. The quill-machines, however, each of which is attended by one woman, have a considerable number of quills ranged in a row, and made to rotate rapidly. In the act of rotation the quills draw off yarn gradually from reels on which it had previously been wound; and the women renew the quills and the reels as fast as the one are filled and the other emptied. A comparison between this operation and that of winding on quills separately illustrates strikingly the saving of time effected by the former. The little quills in the quill-machine, rapidly revolving and feeding themselves with yarn, require but little care from the attendant, who can manage a whole machine full of them at one time.

The yarns for the 'warp' are prepared for the weaver with more difficulty. The skeins of yarn are *put on* a kind of skeleton wheel about two feet in diameter, from whence they are transferred to bobbins about five or six inches long. Here everything seems to be in motion; the wheels or reels on which the skeins are placed, the bobbins for the reception of the yarn, and cylinders or rollers for pressing the yarn close to the surface of the bobbins.

But the most remarkable stage in the proceedings is the next following, of which the cotton-factories also present examples. It is only by closely following the career of a thread through the machine that we can see what processes it undergoes. In the first place nearly nine hundred bobbins are arranged in an upright frame, so that each one can give off its thread without entanglement with the others. The nine hundred yarns, unwinding from the bobbins, pass through nine hundred little eyes or loops, and then between an equal number of meshes or reeds, to bring all into parallel order. Then the whole nine hundred, forming a flat band or layer five or six feet wide, pass between two revolving rollers, the lowermost of which dips into a trough full of paste, by which every thread becomes soaked therewith. Then they pass between horse-hair brushes, one over and one under, each of which is as long as the whole width of the row of threads, and two or three inches wide. The effect of this brushing is to equalize the paste on every separate yarn, very much more equably than it could be effected by a hand-brush. Then, without disturbing the parallel arrangement of the yarns, they are made to pass over a steam-heated copper box or cylinder, whereby the paste is partially dried; and immediately afterwards over a steam-heated iron box, when the drying is completed. The dried yarns next pass through the weaver's 'harness,' that is, small loops in a row of strings; and are lastly wound on the weaver's beam, ready to be put into the loom.

Nothing can exceed the regularity and order of this series of processes. The whole arrangement is about thirty feet long, that is, from the bobbin-frame to the warp-beam the yarn passes along that distance. The contents of all the eight or nine hundred bobbins are collected on one warp-beam, parallel, and in perfectly regular order. The yarn leaves the bobbins in a rough pliant state, and in a few seconds afterwards reaches the warp-beam stifly starched and perfectly dry. The nine hundred bobbins are all revolving at once; so are the rollers; the paste-brushes have a brush-like kind of movement given to them, and the warp-beam is also revolving. Not only so, but the machine keeps its own accounts, for when a certain number of yards of yarn are wound on the beam, the machine rings a bell, and this gives the foreman an intimation which perhaps would not otherwise be so correctly given.

The warp being filled by one sort of machine, and the shuttle-quills by another, the combination of the two sorts of yarn into cloth takes place. The weaving is effected, both by the power-loom and the hand-loom, sometimes in the same factory. In the power-loom, the machine throws its own shuttle, moves its own assemblage of warp-threads, drives up the weft-threads as fast as they are thrown, and winds the woven canvas on a roller. One woman is able to manage two power-looms, to supply warp and weft, mend broken threads, and remove the finished material.

As to the hand-loom, many a person has probably been surprised at the patience with which a man can sit for many hours at a time throwing a shuttle alternately with his right hand and his left, moving a suspended bar alternately to and from him, and treading alternately on a lever with one or the other foot; and may perhaps have pondered how many movements of hand, arm, and foot must be made before a shilling can be earned.

One more process, and our sail-cloth is finished. It is taken to a 'receiving-room,' where it is examined, freed from lumps and irregularities, measured, and weighed. There is also a calender, through which all the canvas ·en passes. This machine consists mainly of one iron and two wooden rollers, which are made to approximate more or less closely together, according to the pressure intended to be given. The canvas is drawn between these rollers, and comes out flat, smooth, dense, and slightly glossed at the surface. It is then made up into compact parcels, called 'bolts,' in which form it passes into the hands of the sailmaker.

These bolts each contain about forty yards of canvas, twenty-four inches in width. There are six or seven different qualities of canvas, according to the size and position of the sail to be made; and each quality has a particular number attached to it, and must have a certain weight per square foot; thus, in the Royal Navy, a bolt of No. 1 canvas, containing thirty-eight yards, must weigh forty-four pounds, whereas No. 7 weighs only about half as much; the intermediate numbers having intermediate weights. The canvas, though woven of stout yarn, is very regular and uniform in its appearance, and of a tolerably white tint.

The first operation in sail-making is to cut up a sufficient quantity of canvas to make a sail; and as the width of the canvas, whatever be its quality, is only two feet, a great number of breadths become necessary. The mainsail of an East-Indiaman contains nearly seven hundred yards of canvas; while the whole suit of sails requires as much as nine thousand yards. Some of the sails are nearly rectangular, some triangular, some of the edges are straight, some hollowed; and the foreman has to pay especial attention to these circumstances in arranging the breadths of canvas. To cut a piece of canvas directly across, the weft or cross-thread is taken as a guide; while an oblique section is marked out by a certain deviation from the direction of the weft. The canvas is not cut by shears or scissors; but a fold being made in the required direction, previously marked with chalk or pencil, two men hold the two ends of the fold, and one of them rips up the canvas with a sharp knife.

The canvas being cut, the sail-makers than proceed to work it up. Their labour consists not only in seaming up the numerous breadths, so as to give the requisite dimensions to the sail, but also in sewing on rope, called 'bolt-rope,' round every edge of every sail: were the sail not strengthened in this manner, it would neither bear the strain of the wind nor furnish fastenings for the ropes by which it is worked. The seaming and sewing are effected with large three-sided needles, of seven or eight different kinds, which are threaded with sewing twine made for the purpose, and having from two to four hundred fathoms to the pound weight. The skeins of twine, previous to being used, are dipped into a trough containing melted tar, grease, and oil, and are twisted round in such a manner as to force the composition completely through the twine, and to expel the superfluous portion. The twine when dry is wound into balls, or on reels, ready for the workman.

The sail-maker, seated on his low stool, holds the canvas before him in a convenient position for working. On his thumb he wears a thumb-stall, consisting of an iron, horn, or leathern ferrule, against which the thread passes, enabling him to tighten the stitches without hurting his thumb. He has also a little contrivance called a 'palm,' consisting of a flat round piece of iron, chequered or grooved on its surface, and intended to act as a thimble: it is sewn to a piece of leather, which enables it to be conveniently attached to the palm of the right hand. The breadths of canvas are joined by stitching or 'seaming,' the stitches having a degree of closeness well agreed upon between master and man, and such as to include rather above a hundred stitches in a yard of length. The seam or overlapping is from an inch to an inch and a half in width. Besides the stitching of the seams, various pieces of canvas called 'linings,' 'tablings,' and 'bands' are stitched on the sail in different directions, for the sake of strengthening it at those parts which are most liable to strain. There are also many small holes to be made in some of the sails, for the reception of short pieces of cordage necessary in reefing the sail.

The bolt-rope which is fastened to the edge of the sails is carefully covered before it is used, to preserve it from rotting: it is first 'parcelled,' that is, encircled with narrow pieces of old canvas; then well tarred; and afterwards 'served' or bound round with a close coil of spun-yarn. The ropes are then sewn to the edges of the sail in a very careful manner; arrangements being at the same time made for the formation of numerous loops, eyes, and other mechanism, necessary for the subsequent guidance of the sail. Different parts of the bolt-rope receive different names according to their position: that which binds the bottom edge is the foot-rope; at the top, the head-rope; at the sides, the leech-rope.

Thus the operation of the sail-maker proceeds, until the whole suit of sails, generally about forty in number, for a ship are made. So well arranged are the plans by which the canvas is cut for the sails, that in some instances not more than three or four yards are actually wasted in cutting up the nine thousand yards for a large ship.

When the sails are finished, they are adjusted to their proper places in the ship by means of the ropes which govern them.

# CHAPTER VIII.

## ROPE-MAKING ; RIGGING ; WIRE-ROPES.

THE part of a ship's fittings next calling for notice is the *rigging* or *cordage.* The material for nearly all our cordage comes from Russia. Some is imported from Manilla, and a small quantity, we believe, from other places ; bnt the great bulk is received from St. Petersburg and the neighbouring parts of the Russian dominions. The quantity which reaches England from that country is immense. In the eight years from 1825 to 1832, there was, on an average, considerably more than a million *poods* imported annually ; a *pood* being a Russian weight, of which sixty-three make a ton ; or, more familiarly, a pood is about thirty-six pounds English. The value of the hemp imported for our manufactures in 1839 amounted to more than six hundred thousand pounds.

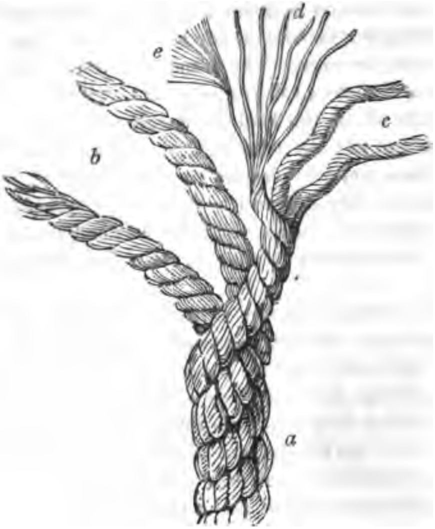
The hemp arrives in England in large bundles, which are separated at the roperies into smaller portions ; or rather, this separation is effected in the hold of the vessels, where the bundles, weighing nearly a ton each, are separated into 'heads' or 'layers,' each containing about twelve or fourteen pounds of hemp. The qualities required in good hemp are, that the fibres should be long, fine, and thin, smooth and glossy on the surface, free from fragments of the woody fibre of the hemp-plant, and possessed of considerable strength and toughness.

Before the rope-maker can begin to use the hempen fibres, it is necessary that they should be straight and parallel, free from dirt, and reduced as nearly as may be to an equal thickness. To effect these preparations the hemp is passed through a process which is termed 'heckling,' or 'hackling,' or 'hatchelling.' On the surface of a small bench before him, each hatcheller has a series of extremely sharp steel spikes, seventy or eighty in number, inserted point upwards, and in parallel order; this is called the hatchel. The workman taking a 'head' or 'layer' of hemp in his hand, strikes it on the points of the hatchel, and draws it between the spikes; repeating this operation several times with each head.

The hempen fibres are not only straightened by this mode of proceeding, but the thicker ones are split by the sharp points of the wires, and all the loose fragments are made to separate and fall to the ground. Sometimes the hemp is moistened with a little whale-oil, to facilitate its progress through the hatchel; and hatchels of finer or coarser texture, that is, having more or fewer wires in a given space, are used according to the kind of cordage into which the hemp is to be made.

The fibres are straightened and prepared, and the accumulation of them into manufactured cordage commences. It is sometimes asked, "Why should the fibres be twisted; why not bind them together in a straight form?" Their limited length (three or four feet) is the chief reason why this twisting is necessary. If the fibres were of sufficient length, the most effectual mode of obtaining their united strength would be to lay them side by side, fastened together at intervals so as to form a bundle or skein; but as the fibres are so short, it becomes necessary, in order to obtain a rope of greater length than that of the fibres, so to twine them together that the friction between and among them shall offer an effectual resistance to any one of them being drawn out from the mass. The manner in which a hay-band is formed from small blades of hay, will illustrate the strength which this kind of entanglement imparts. But this is not all; the entanglement produced by twisting the fibres not only enables the rope-maker to produce cordage of any desired length, but also by making the rope hard and compact, increases its durability, and enables it in a great measure to resist the penetration of water.

The fibres, then, are twisted round one another to form a rope; but here a curious circumstance presents itself for notice. We never see a bundle of fibres simply formed into one twist; for a rope appears to present some twists in a left-handed direction, and others in a right; and also it appears to be made up of smaller ropes. Let us analyse a 'rope's end,' and see how it is built up. We have here a representation of a small piece of cablet (a nautical name for rope, formed in the same manner as, although much smaller than, a cable), which is so dissected at one end as to show the component parts. In the first place we have the cablet itself *a*, presenting the appearance with which most persons are familiar who have ever been on board a ship. By applying a little force to this, we can untwist it, and it then presents to view three smaller ropes, such as *b*, the powerful aggregation of which had formed the cablet. Each of these is known technically as a 'hawser-laid' or 'shroud-laid' rope, meaning thereby a rope formed in the same manner as a hawser or a shroud-rope. Selecting one of these three, and applying a force to untwist it, we find that it is formed of three smaller ropes, such as *c*, which are called in the roperies 'strands;' so that there are nine of these strands in the cablet. Pursuing our analysis still further, by untwisting one of the strands, we find that it is composed of a considerable number of small strings such as *d*, all about equal in thickness; these are called 'yarns;' and if we untwist one of the yarns, we

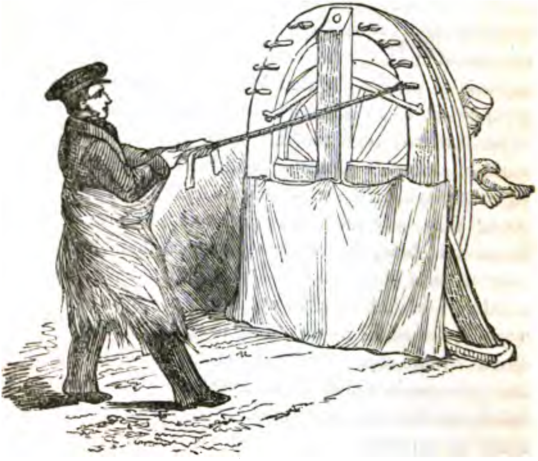


Analysis of a Rope.

arrive finally at the hempen fibres themselves, represented at *e.*

It thus appears, that instead of twisting many hundreds or thousands of hempen fibres one round another, there are successive groups formed, each one augmenting the thickness of the rope previously produced; thus many *fibres* are spun into a *yarn*, many yarns into a *strand*, three strands into a *rope*, and three of these latter into a *cable* or *cablet*. Now for the reason of this. If a cable were formed at once of the individual yarns, twisted one round another, the outer layer would be necessarily exposed to more stress than the internal yarns, since the latter lie at less distances from the centre of the rope. When twisted together the outer yarns would form a spiral of a number of turns round the included yarns, being thereby much shortened; whilst the inner yarns would take only the same number of turns round a reduced axis, being thereby less shortened than the former; from whence it would follow that the outer yarns only would be in full tension, while those within would be more or less coiled up according to their proximity to the centre of the rope. The ultimate result would be, that the outer yarns would break long before the inner ones had borne their fair share of the strain to which the rope might be exposed.

The rope, then, is made at several successive stages, the first of which is the 'spinning' into yarn. At one end of the ropewalk (which is a long open piece of ground, from six to twelve hundred feet in length) is a wheel three or four feet in diameter, round which a band passes in such a manner as to give rotation to a number of small hooks or whirls disposed round a semicircular frame above the wheel. These hooks are from eight to twelve in number, and are each adapted for the spinning of one yarn. The spinners advance, generally in sets of four at a time, to the wheel, and commence that operation which, however simple, is often inexplicable to a bystander, and which we have here sketched. Each spinner has a bundle of hatchelled hemp round his waist, the double, or 'bight,' being in front, and the ends crossing each other behind. With one hand he draws out a few fibres, and fastens them on one of the hooks; while with the other, which holds a piece of thick woollen cloth, he grasps these fibres. A man then turns the wheel, and the spinner walks backwards. It is curious to observe the effect of this double movement. The man draws out



Spinning.

more and more fibres from his bundle as he recedes; and the twist which is given to these by the rotation of the hook makes each length of fibre entangle among or cling to those previously drawn out, while the pressure of the right hand regulates the hardness or closeness of the twist. A little consideration will show that the rate at which the spinner walks backwards, the rapidity with which the hook rotates, and the number of fibres drawn out by each movement of the left hand, are all concerned in determining the thickness of the yarn produced. The men by long practice are enabled so to proportion their movements as to produce any given length of yarn from a given weight of hemp.

In this way the spinners continue to work for hours together, walking backwards while they are spinning the yarn, and forward while the yarn is being wound on a reel. Along the whole length of the 'walk' there are at intervals transverse beams over head, into which hooks are driven; and on these hooks the yarns are suspended when it is necessary to prevent them from trailing on the ground. Each spinner can make about a thousand feet of yarn in twelve minutes. The number of fibres forming each yarn is never reckoned among the rope-makers' calculations; but the yarn is estimated by the *weight* of hemp contained in a given length: thus, a rope three inches in circumference being taken as a standard, and this divided into three strands, the yarns are numbered 18, 20, 25, 30, or 40, according to the number required to form one of these strands, and each of these has a definite weight for a given length. For a three-inch rope of which each strand is to contain twenty yarns, one hundred and sixty fathoms (nine hundred and sixty feet) of the yarn must weigh three pounds and a half. All these are matters which the fingers of the spinner regulate almost intuitively; he does not stop to work out 'multiplication sums,' but produces a 'No. 20' or a 'No. 25' yarn by manipulative adjustments, of which he himself could probably give very little explanation.

We may mention here that nearly all the spinning and twisting concerned in rope-making are or have been more or less affected by machinery in different factories; but in principle the effect is precisely the same whether the hooks be made to rotate by a hand-winch or by a steam-engine applied to a larger apparatus; and we have therefore spoken of the spinning in its simplest and most easily understood form. When a 'spinning-walk' is in full operation, there are twelve spinners at different parts of its length, in three groups, each group being distant three or four hundred feet from the next adjoining, and all the twelve hooks or whirls of the wheel being engaged at once. As the yarns are twisted, they are wound in large bundles upon reels, each reel containing about two hundred and fifty pounds of yarn.

Rope-spinners make a distinction between 'white rope' and 'tarred rope.' When a rope is to be used in the open air, but under cover, it is left in the 'white' state; that is, it is not coated with tar or any other substance. But when it is exposed to the action of water, a coating of some composition is found necessary to enable the hemp to resist the rotting influence of the water; and tar is the substance almost universally used for this purpose. As regards actual strength, an untarred rope is the stronger of the two; but this is more than counterbalanced by the action of water on the hempen fibre. Propositions have at several times been made to substitute for tar some other composition; but we have here only to speak of the method actually employed.

The hemp is tarred (if tarred at all) after it has been spun into yarn, but before the yarns are twisted into strands. The reels of yarn are first 'warped' into a 'haul,' that is, the yarns are unwound from the reel, stretched out straight and parallel, and assembled together in a large group called a 'haul.' This haul frequently consists of between three and four hundred yarns, each a hundred yards in length; and in this state the hemp is tarred. The haul dips into the tar (which is heated to a temperature found to be the best for penetrating to the heart of every yarn), and is then dragged through a grip or gauge, which compresses the yarns so much as to force the tar into every part of the haul, and at the same time squeeze out the superfluous portion. By the aid of a capstan the haul is drawn gradually forward, until the whole has passed through the tar-kettle.

The tarred haul then passes into the 'winding-loft,' where it is wound, by the aid of a simple but ingenious machine, upon bobbins about a foot high, each bobbin being made to contain about twenty pounds of yarn.

The state to which we have now traced our rope is that of a yarn, say one-sixth or one-eighth of an inch in diameter, rough, somewhat uneven, and of a brown colour. This yarn we have next to trace into the form of a 'strand.' As the thickness of yarns is classified according to the number of them required for a three-inch rope, so does the number of yarns combined to form a strand depend altogether on the thickness of rope to be formed. It is this which forms the chief point of difference between different ropes, for the yarns do not differ very greatly in thickness. In the piece of cablet of which a sketch has been given there are only seven or eight yarns in a strand: in a cable twelve inches in circumference there are eighty yarns to a strand; and in the very largest rope-cables ever used in the navy, three hundred and sixty. But whatever be the number, whether as few as seven or as many as three hundred and sixty, they are all twisted uniformly one around another to form a strand. It may be convenient to bear in mind that when the size of a rope is mentioned in inches, it invariably relates to the *circumference*, and not to the *diameter:* thus a first-rate cable of twenty-five inches is about eight inches in diameter, the larger measurement referring to the circumference.

Here we have to speak of one of the improvements effected by the late Capt. Huddart. When the number of yarns in a strand is very great, a difficulty occurs of a kind before alluded to, viz. the unequal strain upon the external and internal parts. About the beginning of the present century Captain Huddart showed that, in order to equalise the strain, the outer yarns of every strand ought to be somewhat longer than the inner, to compensate for the greater circumference round which they have to turn.

Without detailing the various steps by which improvements were introduced, we will at once proceed to the beautiful machine now employed for this purpose. In a skeleton frame, concave towards the centre of the room, are a great number of 'bobbins,' each loaded with yarn ready for being formed into a strand, and each being poised on a pivot so as to rotate with facility. The ends of all these yarns, which may be twenty, fifty, eighty, in number, are made to pass through an equal number of small holes in a convex plate attached to the central machine, and then combined into one close group. This group next passes through a tube, whose diameter is such as to compress the yarns into close contact, and lastly is wound on a large reel attached to the machine. Meanwhile the twist is given to the strand by a remarkable arrangement. The whole of the mechanism, from the tube to the reel, rotates round a horizontal axis; and, in so doing, imparts a twist to the strand which is passing round the various wheels. The different adjustments are very beautiful. In the first place, each bobbin rotating separately on its axis, gives off just as much yarn as the strand requires; so that all become equally strained, by the outer yarns being somewhat longer than the inner. Then the arrangement of the holes in the plate, and of the tube, bring all the yarns to their proper position in the strand: and lastly, by changing the wheels in the machine, the strand becomes more or less hard, by twisting at a more or less acute angle. If the strand be drawn more swiftly through while the machine is revolving with a given velocity, the intensity or closeness of the twist is diminished; if less swiftly, then the twist is increased. The system for attaining any required intensity of twist is called the 'register,' in relation to the means for determining the exact degree of twist in the strand; and hence the whole process has come to be termed, in the technical language of the roperies, *registering*.

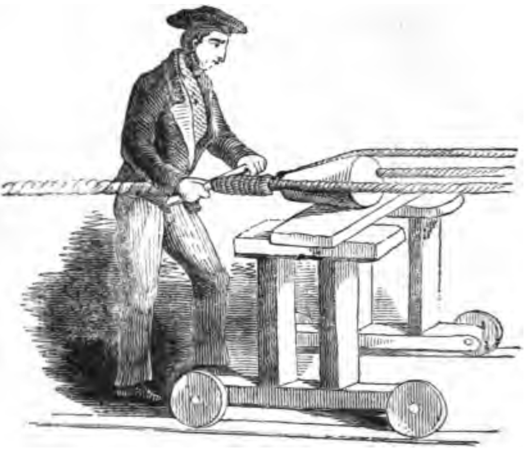
A registered strand, or the strand produced by twisting the yarns together by this machine, is a smooth, uniform piece of cordage, all the yarns twisting round in one direction, and all contributing equally to the strength of the whole. Its thickness varies according to the purpose for which it is intended. Thus a strand for a twelve-inch cable contains eighty yarns, and is about an inch in diameter; while that for a smaller rope would be proportionally thinner. The nature of this machine is such that it can produce an endless strand; for if new bobbins are placed on the frame as fast as the old ones are exhausted, and if the strand is removed from the reel as fast as made, the machine, worked as it is by a steam-engine, may continuously add to the length of the strand.

There is another registering-machine of a larger size, employed for producing strands of greater diameter. There has also been contrived a curious travelling engine, which twists the strands of small diameter. At one end of the ropewalk is a bobbin-frame, similar in principle to the one before noticed, and from this the several yarns proceed through a perforated plate, as in the other instance; but instead of being twisted by a machine which revolves on its own axis, the yarns are fastened to revolving hooks attached to a travelling-carriage which moves on a railway farther and farther from the bobbin-frame as the strand becomes more and more lengthened. The railway extends probably a thousand feet in length; and the machine, which is about a yard long, travels from end to end of this railway in about half an hour, setting in rotation the hooks to which the yarns are attached.

Although the word 'twisting' would express the whole succession of steps, yet the workmen speak of 'spinning' when the fibres are twisted into a yarn, 'registering' when the yarns are twisted into a strand, and 'laying' when the strands are twisted into a rope.

In the 'laying-walk' a revolving wheel, placed near one end, is provided with hooks whereon the three strands to form a rope are fixed (four being sometimes the number, but generally three). These hooks are made to rotate by any of the usual methods, such as turning a hand-winch connected with a wheel which acts on all the hooks, or bringing steam-power into action; both these methods being employed according to the arrangements of the ropery. At the other end of the walk all the strands are fastened to one hook, which revolves in an opposite direction to the others; and it is easy to conceive that this double movement would twist all the three strands round each other. But it is equally easy to see that this twisting would be very unequal, unless other appendages be employed; since the twist would be more close or hard near the ends than at the middle.

The annexed cut represents the singular contrivance for equalizing the hardness of the twist or 'lay.' A conical, or rather, beehive-shaped piece of wood, called a 'top,' is inserted between the three strands, grooves being cut in the surface of the top for their reception. This top, thus placed, prevents the strands from twisting, except in the direction of its smaller end; while a man, stationed immediately behind, compresses the rope by a simple piece of apparatus, and causes the twist to become hard and firm. The top, as the rope closes behind it, is slowly urged on from one end to the other; if small, it is managed by a 'top-man,' but if large, it is supported on a carriage, as in our cut. No difference exists in the



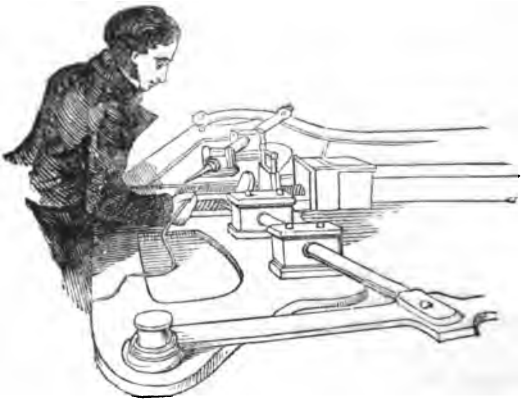
' Laying,' or making a Rope.

making of a larger or a smaller rope, so far as principle is concerned; the three strands are twisted round each other in the same manner, by apparatus more or less powerful, according to the size of the rope. As it is a natural consequence of the twisting process, that the rope should gradually shorten as it is formed, provision is made for this shortening in the arrangement of the apparatus. The wheel to which the three strands are fixed, on three separate hooks, is a fixture at one end of the 'walk;' but the other end of the strands is fastened to a moveable sledge, which is so weighted as to travel gradually up the walk, just as fast as the rope diminishes in length.

A rope thus formed from three strands is the kind which most commonly meets our notice on land, and is technically known as 'hawser-rope,' or 'shroud-rope.' From three such ropes a cable, or cablet, is formed in precisely the same manner; the three being fixed to three revolving hooks at one end, and one at the other; and a travelling 'top' being used to regulate and harden the twist. It may be well to remark, that ropes as ordinarily formed, that is, with three strands, do not require a 'heart,' or central strand, because the angles formed by the union of the three cylindrical strands are such that the pressure, in the operation of laying or closing the rope, causes the strands to fill up the central space completely; but when the number of strands exceeds three, a 'heart' is essential to keep them equidistant from the axis of the rope, and to fill up the vacancy that would otherwise be left by their not meeting in the centre. The heart, however, does not add proportionate strength to the rope, since its fibres, being straighter than those of the outer strands, yield in a different degree.

All arrangements such as the above produce ropes of a definite length, viz., the length of the rope-walk. But some machines have been constructed for 'laying' endless ropes, that is, not only effecting all this twisting and hardening by steam-power, but continuing the process to any required extent; and by such machines ropes have been made with a length of several miles. Of these machines a magnificent series, constructed by the late Captain Huddart, now occupy a place in Her Majesty's Dockyard at Deptford; they are for 'laying' cables of the largest dimensions, and have attracted much attention from engineers. It is worthy of notice, however, in connection with these details, that iron chain cables are now superseding hempen cables of large size; the latter being at the present day seldom made more than twelve inches in circumference, except for Her Majesty's Navy.

A powerful and curious machine is sometimes employed for making *flat ropes*. These are ropes useful in mining operations, and consist of three or four well-made round ropes stitched together side by side. The operation of making these is simply a gigantic kind of thread-and-needle work; yet the force required renders the employment of a complicated machine necessary. Supposing four round ropes are to form the flat rope, four reels are so placed that the ropes can unwind from them with facility, and pass side by side through a steam-heated box, where the tar becomes a little softened, and the ropes more easily



Flat-rope making.

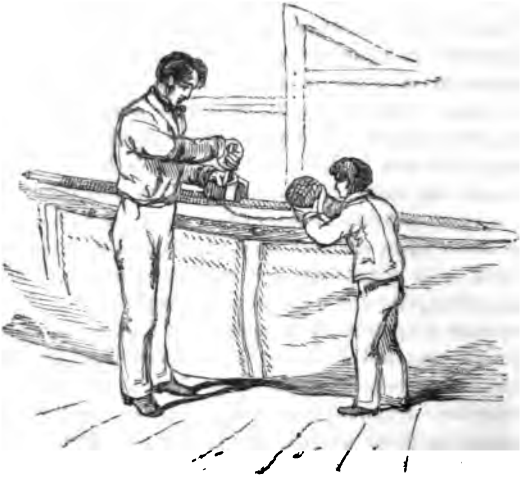
worked. They next pass through a groove or a recess closed in tightly at top, bottom, and sides, except holes at the sides to admit the needles. A piercer, formed of a sharp-pointed rod of steel, probably a foot long and half an inch thick, is then forced entirely through the whole of the four ropes, by a leverage of enormous power; and a man immediately afterwards passes a needle and thread through the whole.

The difference between the varieties of cordage, called *twine*, *cord*, *string*, *rope*, &c., is chiefly matter of detail: the actual formation by twisting being nearly the same in all. The finer and lighter kinds of twine are made of flax, others of fine hemp more carefully heckled than that for larger rope. The spinning here takes the place of subsequent processes in the rope-manufacture, for there is no 'registering' or 'laying' in fine twine. Generally speaking, the twine and small cord manufacture is carried on only to a limited extent by the firms which make the large ropes for shipping; and it presents no marked features calling for our attention here.

Such then are the modes in which ropes and cordage are made; and we are now in a condition to understand the *rigging* of a ship. The rigging of a ship, which is generally understood to imply the whole assemblage of ropes with which she is fitted, is of two kinds, one termed the *standing* and the other the *running* rigging. The former term is applied to all the shrouds, stays, back-stays, and other ropes which are employed to maintain the masts and bowsprit in their proper position, and which remain pretty nearly in a constant state whether the ship is in full sail or all the sails are furled; whereas the *running-rigging* comprises various ropes called braces, sheets, tacks, haliards, buntlines, &c., which are attached to different parts of the masts, yards, sails, and shrouds, and are employed principally in furling and unfurling the sails for the purposes of navigation. The whole of this rigging is made of hempen fibres, more or less saturated with tar. Those pieces of cordage which are devoted to the management of the anchors are termed *cables*; those which are employed in the general operations of rigging, and are more than an inch in circumference, are termed *ropes*; while cordage of smaller dimensions than this is generally called *lines*. But this classification is not sufficient for the purposes of the seaman; every cable, rope, and line has a distinctive name belonging to it, according to the place where or the purpose for which it is applied. The breast-rope, the davit-rope, the quest-rope, the heel-rope, the parral-rope, the bowlines, clew-lines, bunt-lines, tow-lines, leech-lines—however unintelligible to general readers—are associated with perfectly definite ideas in the mind of a seaman, and have a regular scale of dimensions.

There are, we believe, no private ship-building firms which make their own cordage. The government yards have ropewalks for this purpose; but in other cases the cordage is supplied by rope-makers, who confine their operations solely to this department. The cordage is supplied to the riggers in coils and bundles of various sizes, comprising the necessary lengths of all the different kinds of rope and line. The business of a ship's-rigger is distinct from that of a ship-builder; and the operations may or may not be carried on in a ship-building yard, according to the facilities which the yard presents and to other circumstances.

But wherever the rigging may be carried on, the operations are always nearly alike. The rigging-house is a place provided with tackle for stretching the ropes, and with the necessary instruments for attaching the blocks, rings, &c. required for fixing the ropes to the ship, and for managing the sails. The blocks here alluded to are a kind of wheel working in a wooden case, round the circumference of which a rope is passed to act as a pulley. They are sometimes made in the mast-making shop, and at other times by persons who follow that line of business only. The outer case or 'shell' of a block is made of elm or ash, and after being rounded somewhat to an oval form, various perforations are made through it. One of these is for the reception of a pin or spindle, made of lignum-vitæ, or some other hard wood, or of iron; and others are for the reception of the wheels or 'sheaves,' which vary from one to eight in number in each block, and which are made of lignum-vitæ. The adjustment of the repes to these blocks, to iron rings and hooks, and to each other, devolves upon the rigger, who is provided with instruments for cutting, stretching, bending and tyeing the ropes in their proper places. The cordage employed for a large East Indiaman weighs several tons, and some of the ropes are four inches in diameter: the bending and fixing of such ropes as these, therefore, require powerful implements. Among the operations which much of the cordage undergoes before it is taken to the ship, is that of 'serving.' This consists in binding a smaller rope very tightly round it, in order to preserve it both from rotting and from any friction to which it may be exposed. The substance thus bound round the rope is not necessarily a made-rope of smaller diameter, but is sometimes formed of old canvas, mat, plat, hide, or spun-yarn, according to circumstances. All these substances receive the common name of 'service;' and the mode of proceeding may be understood by a description of the process of 'serving' a rope with spun-yarn. The yarn might be simply twisted by hand round the rope, but the necessary tightness and compactness would not be thus attained; and a mallet is used instead. The rope being stretched out horizontally, a man provided with a mallet, and a boy holding a ball of spun-yarn, stand opposite to each other at two or three feet apart. The mallet, which has a concave groove on the side opposite to the handle, is



laid on the rope, handle uppermost. Two or three turns of the spun-yarn are passed tightly round the rope, and round the body of the mallet; and while the boy passes the ball of yarn continually round the rope, the man, at the same time, and in the same direction, winds on the yarn by means of the mallet, whose handle, acting as a lever, strains every turn about the rope as firmly as possible. The yarn then appears like a screw whose threads pass almost transversely round the rope. The annexed cut shows the position occupied by the man and boy while 'serving' a rope.

While describing the process of masting a vessel, we stated that it is only the lower masts and the bowsprit which are fitted by the sheers, the sheer-hulk, or the masting-house. The upper masts are not drawn up till the stage in the proceedings at which we are now arrived, because they require the aid and support of the rigging. The lower masts require to be secured by shrouds, &c. before the others are adjusted to them, so that the raising of the latter takes place after the rigging of the ship has been commenced. We have stated that the topmast surmounts the lower mast, and that the topgallant-mast surmounts both; but the masts are not actually joined end to end, in the usual sense of this term. A few feet below the upper end of the lower mast, a kind of platform is erected, on which the topmast rests, a little in front of the lower mast, so that the two do not actually touch in any part. This platform is called the 'top,' and is supported by various timbers termed cross-trees and tressel-trees. The topmast is drawn up to its place by means of tackle, and fixed securely to the platform, as also to a piece of timber projecting forwards from the extreme top of the lower mast. The platform serves not only as a support to the topmast, but also as a place of attachment for the shrouds by which it is upheld. When the topmast has been raised and properly secured in its place, the topgallant-mast is similarly raised, and adjusted to the upper end of the latter; and in some of the ships of war there is still a fourth mast, of very slender dimensions, called the topgallant-royal-mast, raised highest of all; but it is generally a mere prolongation of the topgallant-mast above the rigging, instead of being a separate and distinct mast. The bowsprit is, like the mast, provided with a kind of topmast or top-bowsprit, by which its effective length is increased. In this manner the vessel is gradually provided with all her masts and yards; the shrouds, stays, and other standing-rigging being adjusted to their places at the same time. The yards too, or the ponderous horizontal spars by which the sails are held, are introduced into the vessel one by one, and attached to the masts to which they belong. Whoever has seen a representation of a ship with her sails furled, must have remarked the vast number of ropes and blocks which connect the various parts of the mast and yards together, and which quite baffle the eye in an attempt to single them out one from another. All these ropes have certain definite offices to perform, and are placed in their respective positions by the rigger.

Hempen ropes, however valuable they may be, seem likely to be in part superseded by ropes made of a very different material.

The use of *iron wire* as a material for ropes is not one of the least remarkable applications of mechanical science which recent years have produced. The use of iron in bars has been known from early ages; but the combination of small wires twisted and interlaced among each other is quite a novel method.

At the Newcastle Meeting of the British Association, Count Augustus Breunner made a communication on the use of wire-ropes in the Harz mines of Germany. About seven years before that period, ropes made of twisted iron-wire had been introduced in place of the flat hempen ropes previously employed. Subsequently they have been adopted throughout the mines of Hungary and most of those in the Austrian dominions, to the almost total exclusion of hempen ropes. These iron-ropes were described as being of equal strength with a hempen-rope of four times the weight. One had been in use upwards of two years without any sensible wear, whereas a flat hempen rope performing similar work would not have lasted much more than a single year. The diameter of the largest wire-rope in ordinary use in the deepest Austrian mines is one inch and a half. The rope is composed of iron-wires each two lines ($\frac{2}{11}$ of an inch) in diameter: five of these are braided together into strands, and three of these are twisted tightly into a rope. The strength of these ropes is little less than that of a solid iron bar of the same diameter. The rope on leaving the shaft requires to be received on a cylinder not less than eight feet in diameter, and is kept well coated with tar. In one instance adduced, there is a saving of about one-third of the former power; for four horses with the wire-rope are doing the same as six horses with a flat rope.

Wire-rope has been used lately as a means of drawing railway carriages, when a fixed instead of a locomotive engine is employed. Those who may have travelled along the Blackwall Railway will have had an opportunity of witnessing the use of wire-rope in this way; iron-wire having been introduced a year or two ago, instead of the hempen ropes formerly used. A wire-rope was lately sent from England to Belgium, for the use of one of the Belgian railways, measuring five thousand three hundred yards, and weighing twelve tons.

As a material for suspension-bridges, iron-wire has been found to constitute a most valuable acquisition. In the year 1834 was completed, by M. Challey of Lyon, a wire suspension-bridge over the river Sarine, at Freyburg in Switzerland.

A remarkable application of wire-rope is in the formation of rigging for ships. Readers of the public journals may have frequently seen announcements relating to this matter within the last year or two. Captain Basil Hall, in his additions to Professor Robison's article 'Seamanship,' in the new edition of the 'Encyclopædia Britannica,' after speaking of the use of iron-chains for cables, slings, topsail sheets, bobstays, and other parts of a ship's fittings, observes:—"Attempts are now making, and we feel convinced that they will ere long succeed, to introduce iron-*wire* rigging, which we consider as stronger and better than chain, because less dependent on the accidental quality and careless manufacture of a single part." Further on he remarks: "We do not think wire will answer for running-rope; but for standing-rigging it may, we conceive, be most usefully substituted for hemp." In the evidence given in connection with a recent trial at Liverpool, it was stated that the "Great Liverpool," a steam-ship of 1400 tons burden, had been fitted up with wire standing-rigging; as had likewise several other vessels. Mr. Shaw, marine manager to the Oriental and the City of Dublin Steam-Packet Companies, has introduced wire-rigging into the vessels of those Companies; and he states the good qualities of this invention to consist in lightness, security, strength, and small resistance to the wind. Captain Bevis, government superintendent of Mails at Liverpool, has stated that upwards of twenty government vessels have been fitted up with the wire-rigging; and the "Great Britain," the enormous steam-vessel which has recently been worked by the screw propeller across the Atlantic, has all her standing-rigging of wire.

In some of the recent inventions respecting the manufacture of wire-rope, the wires are formed into a twisted group before being applied to practical purposes; whereas in others the wires are laid parallel and bound together without twisting. In Mr. Smith's patent, of 1835, a description is given of the mode of constructing the shrouds and stays of a ship with wires. Pieces of wire, all of equal length, are taken, grouped together, and heated at one end in a furnace to a white or welding heat. This heated end is then passed through an opening connected with some of the mechanism of a ship, and beaten up so as to rivet the wires firmly in their place. This plan, and a plan of riveting to various pieces of iron and woodwork, constitute the modes of constructing the rope, the wires not being actually formed into a rope-like group until they are actually attached to the mechanism which keeps them together. In order to preserve the wires from corrosion or oxidation, they are coated or varnished with a solution of caoutchouc, oil, and asphaltum, or some other anti-corrosive composition: and the whole rope or combination of wires required for one shroud or stay is bound round with cloth or cordage previously saturated with the solution. In a patent taken out in the following year, Mr. Smith extends the principle to other objects. He proposes by this patent to group iron wires together, and to combine and secure them by interweaving hempen yarn among them, or by binding them with string or hempen yarn, or by joining them side by side in the manner of flat ropes, or by coating them with strong canvas, and sewing these casings of canvas together. One form of proceeding is thus described:—A proper number of lengths of wire are laid parallel, and coated with an anti-corrosive caoutchouc solution. The wires are then slightly twisted into a strand, so as just to hold together, and to squeeze out the superfluous solution. These strands are then combined into a rope by any one of the methods above alluded to; the hempen or woven material introduced being in all cases previously saturated with the preservative solution.

In Mr. Newall's patent, of 1841, the wire-rope is formed by 'laying' or twisting wires round a central core to form a strand, and by twisting strands round a core to form a rope. The core may be of wire, hemp-cord, spun-yarn, a filament of cotton, or a strip of leather. The combination of the wires into a strand is effected by rather a complicated assemblage of machinery, in some degree combining the character of the machines for making hempen ropes and of those used in spinning cotton.

In the same year another patent was obtained for wire-ropes composed of six strands laid round a core, each strand being composed of six wires laid round a core; the cores being saturated with a preservative solution before the wires are twisted round them. This, like the former method, is effected by rather complex mechanism. Other contrivances have been brought forward in different quarters; and the system generally has become so far valuable as to lead to inquiries as to the validity of some of the patents, their priority over others, and so forth: a pretty sure test at all times that the invention itself is deemed a valuable one.

## CHAPTER IX.

### ANCHOR-MAKING.

AMONG the peculiarities which distinguish a floating body from one that moves on land is the difficulty of staying the progress when motion is no longer desirable: however valuable winds and currents may be as sources of motion, yet the very facility which they present for that purpose renders it difficult to stop a floating body, such as a ship, when under the influence of either. In fact, no plan has hitherto been devised but that which may, in familiar terms, be called hooking the floating body to the solid bed beneath the water; for an anchor may be deemed a hook, caught or entangled in the solid bed beneath the ocean, and connected with the ship by a rope.

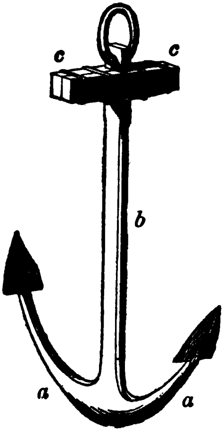
The early substitutes for an anchor seem to have been large stones, baskets full of stones, logs of wood loaded with lead, sacks filled with sand, and other rude and heavy contrivances. In our own day, boats and other small vessels employ what are called 'grapnels,' consisting of a series of five or six hooks arranged round in a circle, so that one or other of them is almost certain to cling to the ground or to any other body when thrown upon it. In the East Indies a sort of anchor is employed called the 'mushroom anchor,' from its great resemblance in shape to that plant: it is a hollow cup, the edge of which digs into the ground and clings to it sufficiently firm to maintain a hold. Anchors of a peculiar kind have sometimes been used under the name of 'floating anchors.' These are intended to stay the beating about of a vessel in some degree at spots where the sea is too deep to be fathomed by the cable to which a regular anchor is attached.

Another kind of anchor occasionally employed is that called the 'mooring anchor,' used for securing vessels in certain situations in harbours or roadsteads. As these anchors do not require to be lifted into the ship, but are fixtures in the harbour, there is no need to adopt any particular form, provided the weight be sufficient to retain a vessel in its place. A mooring anchor often consists merely of a ponderous block of stone, with a ring fixed in the middle of the upper side; or several large stones are fastened together, so as make one effective whole. Sometimes one of the largest anchors used for a first-rate ship, weighing eighty hundredweight, is selected, and one of the arms or flukes is beaten down close upon the shank, to prevent it from entangling the cable connecting the vessel with the anchor: this is usually done only when one of the flukes of a large anchor is damaged and unfit for use. About thirty years ago Mr. Hemman of Chatham devised an improved form of mooring anchor, made of cast-iron, and very massive. The form bore some resemblance to that of a spade; and when the edge had once penetrated the ground beneath the water, it was calculated to take a very firm hold.

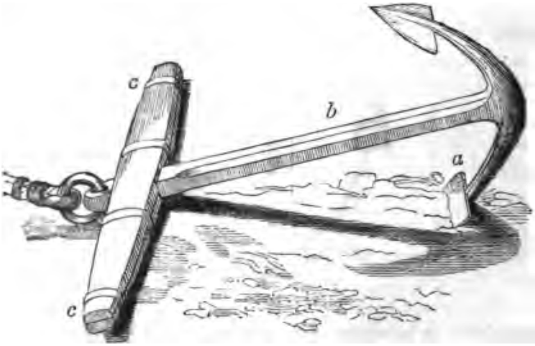
But the anchors most important of all are those which a ship carries on board, and which are used as occasion requires to stop the progress of a vessel. Ships of the first class carry seven anchors; and the smallest class, such as brigs, cutters, and schooners, usually have three, varying in size according to the class of vessel. Different names are given to the anchors of a large ship. The *sheet* anchor is the largest of all, and is stowed away in the fore part of the vessel, on the side called by seamen the larboard: it is only used in cases of great necessity, or when the ship is beset by heavy gales. The *bower* anchors are either two or three in number, the largest being nearly equal in size to the sheet anchor: the name used to be *bowyer*, from the bow, the end of the ship from which the anchor is suspended. The *stream* anchor is much smaller than the bowers, generally not above one-fourth or one-fifth of the weight: it is used principally in streams and rivers of moderate force. The *kedge* anchor is the smallest of all, being only half the weight of the stream anchor; it is used principally to assist in what is called 'kedging a ship,' that is, to bring a ship up or down a narrow river by means of the tide, though the wind be contrary.

The largest anchor in a first-rate man-of-war weighs as much as ninety hundredweight; in an eighty-gun ship, seventy-six hundredweight; in a seventy-four-gun ship, sixty-eight hundredweight; and so on down to the smaller vessels.

In order to understand the mode in which the fluke of an anchor is made to cling to the ground when cast into the sea, it will be necessary to speak of its general form. The first cut represents an anchor in its vertical position, and the second its position when one of the flukes has penetrated the soil beneath the sea. The hooked arms (*a*, *a*) are terminated at the ends by tolerably sharp points,



calculated to penetrate into the ground; and when one of these arms has taken fast hold, the motion of the vessel tends rather to increase that hold than to diminish it, on account of the concave form which the arm presents: the vessel can then only move by one of three things happening—the fracture of the arm from the other part of the anchor; the fracture of the cable connecting the anchor with the ship; or the ploughing up of the soil by the arm immersed in it, and the consequent liberation of the anchor. The extremity of each arm is increased in width, and forms the blade, on which is fixed a broad, flat, triangular plate, called the palm: the use of this palm is, by exposing a broad surface, to take a firmer hold of the ground. The peak, or bill, is the sharp extremity which first penetrates into the ground. Sometimes each arm is curved, as we have stated; but in other instances it is quite straight, the two arms making a definite angle with the shank or upright portion. This shank (*b*) is a strong iron bar or assemblage of bars



connecting the arms with the stock (*c*, *c*), a powerful wooden cross-piece, at right angles to the direction of the arms: the lengths of the stock and of the shank contribute to make one of the arms penetrate the earth. A ring at the upper end of the shank serves for the attachment of the anchor to the great cable by which it is held.

Were it not for the cross-piece called the stock, it would be difficult to ensure the catching of either of the arms in the ground; but they enable that effect to be almost always ensured in the following manner:—The anchor, when on board, is placed in a situation convenient for dropping into the sea. To the ring is attached one end of a cable, which is either a stout rope or an iron chain; and this cable is arranged along the deck in long coils, perfectly free from all confusion or entanglement, the remote end of the cable being firmly attached to a proper place on deck. When the anchor is let go, it falls into the sea, descends rapidly, and draws the cable after it so violently, that it is often necessary to throw water on the woodwork against which the cable rubs, to prevent it from taking fire. The anchor pitches violently on the ground with the arms downwards, and neither peak in such a position as to enter the ground; but it presently falls over, and in so doing, the position of the stock at right angles to the arms, and its length and height, together with the weight of the cable, are sure to throw it with one of the arms pointed into the ground.

The weighing of an anchor, or the drawing it up from the anchoring-ground into the ship, is an operation requiring the joint exertions of a great number of men. A sort of windlass, on a very enormous scale, called a capstan, is erected in a particular part of every ship, and round this windlass the cable holding the anchor is wound; or, if the cable be of too great diameter, a smaller rope wound round the windlass, draws in the cable. The capstan has a number of holes arranged round its circumference, and into these holes the seamen insert long bars, which then appear like radii or spokes of a wheel; the bars act as levers, and by their aid the men are enabled to turn the capstan. The vessel is gradually drawn nearly vertically over the anchor, which is thus raised on end, and liberated from its hold on the ground without difficulty; the anchor is then weighed, and stowed away in its proper place.

There is perhaps no kind of smith's work more gigantic than that of anchor-making: the large masses of iron employed and the mechanical force necessary for welding the several parts together render the employment of powerful apparatus indispensable. The finest establishment for anchor-making at present is, we believe, the Royal Dockyard at Woolwich, where the bellows and the hammers are all worked by steam-power, and where various improvements in the manufacture have been introduced. But we shall find it convenient to speak of the more common modes of manufacture by manual labour.

The several parts of an anchor are made separately, and then welded together: the shank, the arms, the palms, the ring, &c., are attached to each other after they have had the necessary forms given to them. The most ponderous part of an anchor is the shank, or perpendicular bar, and as this is, in a large anchor, nineteen feet long, and ten or twelve inches thick, it would be impracticable to form it out of one piece of iron; it is therefore built up of a great number of pieces welded together into one solid mass. The general form in which this is done, except when the modern improvements of Mr. Pering, Lieut. Rodgers, or Mr. Porter are adopted, is as follows:—Four iron bars of comparatively small diameter are laid together in the form of a square; on each side of this square smaller bars are laid, perhaps ten or twelve in number, so as to give to the mass a somewhat circular form: outside these are ranged thirty or forty bars like the staves of a barrel, so as to make the mass both larger and more nearly cylindrical. Finally, iron hoops are driven over the bars at certain intervals along their length, to bind them all together. The mass is then heated to a welding heat, and hammered till all the bars combine into a compound mass of iron, of which the separate pieces are not distinguishable.

But in this mode of making the shank certain serious defects are found. The mass is so thick, and the separate bars are so numerous, that the effect of the hammering scarcely reaches the central bars; and moreover the outside must be heated in the fire to a destructive degree before the centre can be brought to a proper welding heat; so that in many cases the outside only is perfectly welded, the inner portions being left nearly in their original state. To remedy this defect, Mr. Pering, clerk of the cheque at Plymouth, devised a mode of making the shank of broad bars equalling the whole diameter of the shank, laid flat one on another, welded at two heatings and bound with iron hoops. Still more recently Lieut. Rodgers has devised a hollow shank on a principle which is well understood by engineers, and which is beautifully shown in nature by the form of the bones of animals; that is, that if a given weight of material be formed into a hollow column or pillar, the column will possess more strength than if it had the same amount of material and were made solid: the greater diameter of the hollow column increases the resistance to fracture, without the weight being increased. This is only one of the numerous improvements which Lieut. Rodgers has introduced in the form of the anchor.

It may reasonably be supposed that the heat required to bring such large masses of iron to a welding state must be very intense, and that the removal of the masses from the fire to the anvil must be done speedily to prevent loss of heat. On the ground of the anchor-smith's shop a brickwork hearth is erected six or seven feet square, and at the back of the hearth is erected a strong brick wall, faced with fire-stone at the part likely to be exposed to the fiercest heat. At some distance above the hearth is a kind of dome with a chimney in the centre through which the smoke from the fire escapes. The fire is built up on the hearth in a singular manner, the coals being ranged round so as to form a hollow oven. In the first place a layer of coals is spread evenly on the hearth, then some large cinders are ranged round in a circle, and this circle is gradually carried upwards and inclined inwards until it meets at the top. The construction of a boy's grotto with oyster-shells would not be a bad mode of illustrating this. A door or opening is left in one side of the coal-made oven, into which the end of the mass of iron is introduced. The shank being, as we have said, sometimes as much as nineteen feet in length, only so much of it is heated at once as can be hammered or welded by the men before it gets cold; and this amount of its length is just able to be contained in the coal-oven.

When the several bars of which the shank is to be formed are ranged in their proper places and secured by hoops, the whole mass is suspended from a crane, which has such a facility of motion, that one man can turn the crane towards the forge and introduce one end of the shank into the fire. As soon as this is done, the orifice round the shank is filled up with pieces of coal, so that the iron is completely surrounded by blazing coals on every side: here it remains for a space of time varying from half an hour to an hour, according to circumstances, a fierce heat being maintained the whole time by means of immense bellows. These bellows are (except where steam-power is employed) worked by the same gang of men, eight or ten in number, who afterwards forge the iron when hot. The bellows, situated on the opposite side of the vertical wall to that where the fire-place is erected, are two in number, and resemble the common domestic bellows rather than those employed by the generality of smiths, that is, wind is forced out only at the downward pressure of the upper boards. A chain rises from the handle of these bellows, and is attached to one end of a lever in such a way as to enable two or more men, by working the lever to and fro, to set the bellows in action. While some of the men are at work at the lever in order to raise the upper board, by which air gains admission into the bellows, others are standing aloft so as to get on the upper board when it is raised, and by their weight to press it down again: one bellows is being worked upwards while the other is being pressed down, so that the men mount from one to the other alternately. This rude mode of working the bellows is scarcely worthy of the mechanical ingenuity of the present day, and it is no wonder that steam-power has been partially substituted for it. A small hole lined with iron penetrates the brick wall close to where the fire is kindled, and into this hole the nozzles of both pairs of bellows are introduced, so that the wind is impelled directly into the fire. If the coals forming the hollow oven become in any place burnt through to the external air, the fireman immediately covers the spot with new and damp coals, so as to confine the heat entirely to the central parts which immediately surround the metal.

The shank of the anchor is turned over several times while in the oven, in order to become equally heated in every part; and when thoroughly heated through to the welding temperature, it is drawn from the oven, and the crane from which it has all along been suspended is moved round so as to bring the heated part over a solid block of iron lying on the ground, which serves as an anvil. The men now arrange themselves in regular order: one man, who acts as foreman, looks on and points with a wand to the particular spot where the blows are to be directed; one man grasps an iron bar attached to the remote end of the shank, by which he is enabled to turn it round as occasion may require; and the other men, generally either six or eight in number, arrange themselves nearly in a circle, and with heavy hammers, weighing sixteen or eighteen pounds each, strike the red-hot iron. They all strike in succession and with the greatest regularity, and all strike on the same spot, until the foreman points to a new one. The hammers have steel faces, and are furnished with very long handles; they are wielded over the head and shoulder at full arm's length, and fall on the iron with powerful effect. When the iron has so far lost its heat as to be incapable of further welding, several iron pins are driven in in a curious way. The foreman takes a pin (a sort of thick nail without a head) in a cleft stick, and places its point close to the iron, which, though not hot enough for welding, is still soft and yielding: a few powerful blows with the hammer drive the cold hard nail into the soft and yielding iron: the effect of this is to condense, harden, and secure the various pieces of iron together more effectually.

When the end of the shank has been thus welded to the proper form, it is again put into the oven, which is prepared to receive it, and which has now a hole broken through in the opposite side to that at which the end enters. The object of this is, that the part already welded may be thrust out beyond the reach of the fire, and another portion exposed to the action of the heat. When this portion has attained a welding heat, it is removed from the fire by the same means as before, and hammered on the anvil till it has assumed the proper form and proper degree of compactness. These successive heatings and hammerings are continued until the whole length of the shank has been thus treated; and afterwards the shank is hammered again to make the surface smooth and even, and to fill up any little pores or apertures which may exist in the surface, and which, if left unremedied, might form lodgments for sea-water, and thus become rusted.

But powerful as is the effect of the long continued beating by six or eight heavy hammers, yet the consolidation is not so completely effected as by means of one enormous hammer or ram, called a Hercules. This nearly resembles the ram or monkey used in pile-driving, for laying the foundation for the piers of bridges, &c. The ram is a mass of iron weighing about five hundred pounds and capable of sliding up and down in a kind of groove. A strong rope is fixed to the top of it, and to this rope are spliced the ends of six or eight others. As many men are employed as there are ropes, and they conjointly draw up the ram to the height of seven or eight feet, then letting it go, it falls with a powerful effect on an anvil placed beneath it. This anvil is so situated that the heated end of the shank may, by turning round the crank from which it is suspended, be brought immediately upon the anvil. It is considered that the comparatively few blows given by this ram are more effective than the numerous blows given by six or eight hammers. In the government establishments where steam-power is employed, an enormous tilt-hammer, weighing several tons, is employed for this purpose. Still more recently a *steam-hammer*, devised by Mr. Nasmyth and used with marvellous effect in pile-driving, has been successfully applied to anchor-forging.

The shank has generally a somewhat circular or octagonal form given to it; and the two ends have to be so cut as to form scarfs or grooves for receiving the other parts of the anchor. These grooves are made by cutting away some of the metal while still hot, with steel chisels, and then perfecting the shape by means of stamps or punches. All this is done with comparative ease while the iron is hot and yielding.

This description of the processes by which the shank or long shaft of the anchor is formed, will apply to most of the other parts, except that all the latter are of much smaller size. The arms are being made at another forge, and by a separate set of men, while the shank is forming. They are shaped in the various parts according to the required pattern, and generally have a curvature given to them, though in some instances they are made quite straight. A scarfing or groove is made at the thicker end, to correspond with that at the lower end of the shank; and when these two grooved ends have been heated to the proper point, they are laid together and welded on the anvil. But in some anchors the arm is not united to the lower end of the shank in this manner; an alteration was introduced by Mr. Pering, in which the lower end of the shank is made to bend round to meet the arms, so that the transition from one to the other is a curve, and not a sharp angle, at the same time that there is no actual joint at the spot separating the shank from the arms. In Lieutenant Rodgers's anchors nearly all the parts are formed in a manner peculiar to himself, and displaying great ingenuity.

By whatever mode the arms are attached to the shank, the broad palms are fixed on separately: these palms are sometimes made of sheet-iron forged to the proper shape and thickness; or of several bars laid side by side, and forged into one piece, like the bars of which the shank is made. The enormous ring by which the anchor is suspended from its cable, is attached to the upper end of the shank, where a hole is bored, or rather punched, for its reception: this hole is made by steel punches while the iron is hot; small punches being used first, and larger ones afterwards. The ring is made of several small bars welded together, drawn out into cylindrical form, put through the eye or hole in the shank, bent into the form of a ring, and the two ends welded together. When the whole of the ironwork of the anchor is put together, it is heated to a lower temperature than before, and every part is beaten with hammers of a rather smaller size than the sledge. This hammering is continued until the metal becomes black and cold; the object being to render every part as hard and smooth at the surface as possible, in order the better to resist the rusting effect of sea-water.

The anchor is now to be provided with a stock—that cross-piece (generally formed of wood) which is attached to the upper end of the shank, a little below the ring. The common form of the stock is this:—Two beams of oak are made to embrace the upper end of the shank, and are firmly united by iron bolts and hoops; these beams are about the length of the shank, their united thickness at the middle is about one-twelfth of the length, and they taper off gradually towards the two ends. The stock is kept in its place on the shank by means of two projecting nuts or iron blocks placed above and below it. The stock has been of late years frequently made of iron: in this instance it consists of a long cylindrical bar, about half as thick as the shank of the ancher; but instead of passing round the shank, as the wooden stocks do, it passes through a hole bored in the upper end of the shank. Stocks of this kind are chiefly useful where it is desirable to take them out of their places for the convenience of stowing away the anchor on board a ship. When the stock is put through the hole in the shank, it is secured there by a kind of linch-pin, which holds it securely.

The most recent and important improvement in anchors is that due to Mr. Porter, in which the main part of the anchor is connected with the shaft by a swivel or hinge.

# CHAPTER X.

## IRON STEAM-BOATS; MARINE ENGINES; LOCOMOTIVES.

How the labours of many men led to the gradual development of the idea that steam might be brought to act as a moving-power for ships, has been the subject of many elaborate treatises and many bulky volumes. When the Marquis of Worcester, in his 'Century of Inventions,' spoke of an invention by which he could "make a vessel of as great burthen as the river could bear to go against the stream, which, the more rapid it is, the faster it shall advance, and the moveable part that works it may be, by one man, still guided to take the best advantage of the stream, and yet to steer the boat to any point"—it is supposed that he alluded to some kind of steam-engine; but we are left wholly in the dark as to whether the matter was anything more than a speculative conjecture in his own mind. Savary and Papin tried to bring steam to bear upon navigation; and in 1737 Jonathan Hulls published a pamphlet in which he explains a clumsy but ingenious mode of constructing a steam-boat; but there is no evidence that he reduced it to practice. Then followed Daniel Bernoulli's essay on the practicability of propelling vessels by paddle-wheels urged by steam; then a similar essay by Gautier; then a proposal, by a Genevese minister, to use propellers acting on the principle of the duck's foot; then various plans proposed by D'Auxiron, Perier, and Jouffroy, in France, and by Rumsey, Fitch, and Evans, in America—all exhibiting more or less ingenuity, but failing either in principle or in practicability.

At length we come to the series of proceedings by which the two northern cities, Edinburgh and Glasgow, honourably distinguished themselves, long before London did aught in the cause of steam-navigation. In 1787 Mr. Miller, of Dalswinton in Dumfriesshire, while describing a contrivance for moving boats by paddles worked by men or horses, remarked:—"I have reason to believe that the powers of the *steam-engine* may be applied to work the wheels, so as to give them quicker motion, and consequently to increase that of the ship." The idea is said to have been suggested to him by a young man in his service, Mr. James Taylor; and Miller obtained the aid of Mr. Symington, a civil engineer of Edinburgh, in working out the idea. A small engine was accordingly made at Edinburgh by Mr. Symington, and sent in 1788 to Dalswinton, where it was placed on one side of a double pleasure-boat, the boiler being on the other side, and the paddle-wheels in the middle. The apparatus was tried in a small lake, and Mr. Miller had the pleasure of seeing his little bark move along at the rate of five miles an hour, being perhaps the first really successful instance of the kind. He then caused engines and paddles to be fitted to one of the large boats on the Forth and Clyde Canal; and towards the end of the year 1789 many short trips of an experimental character were made with this boat, a speed of six or seven miles an hour being attained. For some reason or other Mr. Miller ceased to pay any further attention to the matter; but the success of his attempts drew attention more prominently to the subject.

From 1789 to 1812 the experiments made in England and Scotland in furtherance of steam-navigation were not attended by any marked results. Earl Stanhope constructed a vessel with duck-foot paddles, which, however, did not travel faster than three miles an hour. Mr. Symington made a steam-tugboat for the Forth and Clyde Canal, which he was afterwards obliged to abandon, because the Company—correctly or incorrectly— supposed the motion of the paddles would injure the banks of the canal. In 1806, Mr. Fulton, of America, after making some experiments in France, procured all the practical information which Symington, Miller, and others could give him in Scotland, and succeeded after a time in running a steam-boat on the river Hudson, in America, from New York to Albany: being the first instance of a steam-boat commercially used as a passage-boat, the preceding attempts in Scotland having been rather experimental than commercially practical.

It appears that Mr. Henry Bell, whose name is associated with the rise of steam-navigation on the Clyde, had been instrumental in procuring for Fulton various items of information from Mr. Miller; and in a short paper which he contributed to the 'Caledonian Mercury,' in 1816, after alluding to a letter which he had written on the matter, he uses this remarkable expression:— "This letter led me to think of the absurdity of writing my opinion to other countries, and not putting it in practice myself in my own country; and from these considerations I was roused to set on foot a steam-boat." He made many attempts with partial success, and at length produced the little steam-boat "Comet," which will always be remembered in connection with this subject, as the first steam-boat made in Europe which successfully plied as a passage-boat. It was built by Messrs. Wood, of Port-Glasgow, on the Clyde. It was only forty feet in length of keel, with about ten feet beam; its tonnage was about twenty-five tons, and it was worked by a little engine of three-horse power. The Comet plied on the Frith of Forth, between Grangemouth and Leith, a distance of twenty-seven miles, which it was accustomed to do, in ordinary weather, in about three hours and a half. The little steamer was at length lost on the Doors of Dorrismore; but the tiny engine was recovered, and has since been carefully preserved by one of the engineering firms of Glasgow. When the British Association held its meeting in Glasgow in 1840, two relics were exhibited in the model-room which excited much attention from those who watch the mighty progress of steam-power: viz. the small and rudely constructed steam-engine on which James Watt made many of his experimental researches (and which is preserved in one of the rooms at the Hunterian Museum in Glasgow University); and the small engine which Henry Bell had used in the Comet steam-boat.

It was in 1813 that the Comet effectually solved the problem of steam-navigation on British rivers; and from that time the tide of enterprise set in strongly in that direction. In March, 1815, Mr. John Thomson started the "Elizabeth," a steamer fifty-eight feet in length and of eight-horse power; and numerous other steamers rapidly followed, principally on the Clyde and the Forth; Glasgow, Greenock, and Port-Glasgow becoming by degrees the scene of most extensive arrangements both as respects the vessels themselves and the engines whereby they were propelled.

Iron steam-boats have been one of the most marked objects of improvement in steam-navigation; and the builders in the Clyde and in the Thames have not been slow to follow the example set to them in this matter by (we believe) the Liverpool builders. The chief points of difference between iron steam-boat building and the building of a common wooden vessel, are as follow:— In the construction of a timber-built ship, as before explained, the keel, the ribs or timbers, the stem and stern-post, and the planking, constitute the main pieces which give shape and stability to the hull of a ship. Now in an iron steam-boat all these parts are made of iron; and the appearance of an iron steam-boat yard consequently differs much from such a one as was formerly described. There are no huge trunks of oak lying in heaps in the yard; no 'converting' sheds, where the business of sawing and shaping the timbers is carried on; no 'steaming-tank' for steaming the planks preparatory to bending round the contour of the ship; no trenail-cutters, no oakum-spinners. But instead of these there are workers in iron, with their forges, their powerful punching-engines, their enormous cutting-machines, which will sever a bar of iron as if it were a piece of ribbon, their anvils, their hammers, their rivet-furnaces; while around are lying sheets of iron from the rolling-mill, and bars from the drawing-mill, with guide-pieces for bending them to the required form. We have iron bars instead of timbers, sheet-iron instead of planks, rivets instead of trenails, forges instead of sawpits, and iron scraps instead of chips of wood.

There must be a ship-draftsman for an iron ship as well as for a wooden one, and he lays down the draft of a ship nearly in the same manner. He selects a large flat surface of flooring, and on this he chalks a series of lines destined to show the exact size and shape of the various 'ribs' of the ship; and it is here that any improvement suggested in the form of the vessel's hull must show itself, preparatory to the mechanical operations of the ship-builder. The process is not so complex for an iron ship as for a wooden one; since the draftsman, in the latter case, has to indicate not only the height and curvature of the various timbers which constitute the framing, but also the 'scantling' or breadth and thickness of every individual piece at every part of its length. In iron vessels this trouble is saved, since the contour or cross-section of every rib is given to it while yet in the state of an iron bar. In building wooden ships a large number of 'mould-boards' or thin pieces of wood are prepared, in exact conformity with the chalk-lines on the mould-floor, as guides to the sawyers in cutting the timbers: but for iron ships thin rods only are necessary, sufficiently firm to give the curvature to the several ribs.

The keel is laid down in a slightly declining position from stem to stern, as in wooden vessels, for the facility of launching; and, like it, is generally formed of several pieces fastened end to end. But these pieces are of iron instead of wood, and are of much smaller 'scantling.' An iron keel six inches deep by three wide will suffice for a vessel of one thousand tons burthen! The various pieces of which it is formed are bevelled off at each end, so that each one may furnish a recess for receiving the other; and the two are fastened by iron bolts or rivets driven into holes bored for the purpose. The keel, standing up on one edge, exhibits a range of holes from end to end; and these are intended for the reception of the rivets which are to bind the keel, the ribs, and the 'skin' of the vessel together. The pieces of iron which form the stem and sternpost are bent to the required form before being brought to the yard, and are then riveted to the ends of the keel: for it may be observed generally that rivets form the almost universal mode of fastening in an iron boat.

Perhaps nothing in the appearance of the skeleton of an iron vessel strikes a stranger as being more remarkable than the extreme slightness of the ribs, compared with the bulky timbers of a wooden vessel. Their cross-section is neither quadrangular nor circular, but may be described as exhibiting a square from which a quadrant has been removed at one corner. A bar measuring three inches on each of the two sides, by three-quarters of an inch in thickness, will constitute the rib for an iron vessel of considerable dimensions. The form thus given seems to be intended to afford facilities for boring holes for the reception of the numerous rivets by which the ribs are fastened to the other parts of the vessel. The iron is brought to the exact form in the rolling-mill, where it passes between two rollers so grooved as to give the cross-section required. When it is about to be wrought into the form for the ribs of a ship, it is cut to the proper lengths, heated in fires or furnaces close to the place of working, and bent round to the required curvature on anvils; the curved rods before alluded to serving as guides to the attainment of the proper curvature. These pieces, when formed to the desired shape, are carried to the building-slip, and there riveted to the keel, at distances of from twelve to eighteen inches apart.

The sheet-iron which forms the planking or 'skin' of the vessel is a much more manageable material than the stout oaken planks employed in building wooden ships. It is rolled into sheets at the mill, of such thickness as may be desired, and cut to the requisite length and width by the powerful shears which are used in most iron and engineering works. The sheets are then brought by hammering to the proper curvature for bending round the exterior of the vessel, a guide or gauge being employed to regulate and determine the degree of curvature. They are then fastened to the ribs and to the keel by means of rivets, the number of these fastenings being extremely large.

When the keel, the stem and sternpost, the ribs, and the sheet-covering are all put together, the distinguishing characteristics of an iron ship are nearly at an end; for the interior and upper fittings bear a pretty close analogy whether the vessel be of iron or of wood. Bar-iron for the ribs, sheet-iron for the covering, and bar and cast-iron pieces for the beams and a few other parts, constitute the metallic skeleton which is afterwards to be decked out with the finishing appendages. The following description of three iron steamers, making by the same firm at the same time, will illustrate the peculiarities of this art. One was on the building-slip, the keel laid down, the stem and sternpost erected at the ends, and about one-half of the ribs set up, constituting a skeleton whose lightness contrasted strikingly with the heaviness necessarily involved in the frame-skeleton of a wood-built vessel. Another was a very small sailing-vessel, whose progress illustrated the extraordinary rapidity with which iron vessels can now be construeted; the keel had been laid down about a fortnight, and the vessel was expected to be in sailing order in another week; workmen being engaged on it as thickly as they could ply together. The third was a fine steamer, which had left the building-yard, and was being supplied with the engines and machinery. It was a vessel of seven hundred tons burthen, and three hundred horse-power; it was about two hundred feet long, by twenty-seven 'beam' or width, and had paddle-wheels twenty-six feet in diameter. Most of the rougher portions of the work were completed; and painters, gilders, cabinet-makers, &c. were fitting up the interior in a splendid manner. This, like the other two, had keel, ribs, beams, exterior coating, &c. of iron, and was an elegant specimen of this most remarkable constructive art.

The manufacture of marine steam-engines, like that of iron steam-boats, is largely carried on in the Clyde. In the 'Gazetteer of Scotland,' the celebrated engine-works of Napier at Glasgow are described as having "supplied the engines of the British Queen; and in the course of one year, ending in October, 1840, he supplied six first-rate steam-ships with their engines, viz. two frigates and four Transatlantic liners. The first two were the Vesuvius and Stromboli, which took up a worthy position at the siege and capture of St. Jean d'Acre, on 4th November, 1840; and the latter four were the Britannia, Arcadia, Caledonia, and Columbia, now employed in carrying the mails between Liverpool and Halifax and Boston, North America. These liners were all built in the Clyde, are each of one thousand two hundred tons burthen, and propelled by engines of four hundred and forty horse-power." Since then, the East India steamers Berenice, Zenobia, and Victoria have also been provided with their engines from the same works. In short, the firms which are now engaged at Glasgow in marine-engineering works, including the names of Napier, of Craig, and of Todd and Macgregor, have most amply taken their share in the recent advancement of steam-navigation.

To describe all the separate pieces of a marine engine, how they are made, and how put together, would be about as practicable and as interesting as to describe all the minute pieces of a watch; both would require thorough practical knowledge in the writer, and indomitable patience in the reader. But an idea of the general manufacturing arrangements involved would tax neither the one nor the other so highly; and this we will endeavour to convey.

In the first place the metal which is to be wrought up into a marine engine (and into other engines likewise) reaches the factory mostly in one of three states—rough metal for castings, bar-metal for shafts and other stout purposes, and sheet-metal for extensive surfaces. We here speak of iron, as being the metal incalculably more used than any other for such works; and we therefore expect to find, in a large engine-factory, the mechanical arrangements necessary for working up iron in these three states. We shall perhaps find this subdivision as well fitted as any for the popular sketch we have in view. The buildings incident to such a manufacture comprise a casting-house or foundry, a boiler-house for making sheet-copper and iron boilers, a smithy for working up coarse metal, and engineering-shops for making delicate parts of the machinery.

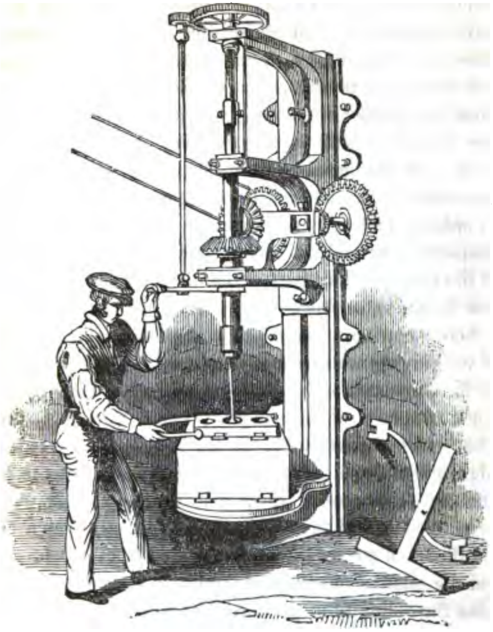
Let us next notice a little closely a few of the operations here indicated. We may begin with the boiler. This very important part of a steam-engine, when it is considered that water and high-pressure steam have to be contained in it, may well be supposed to require careful manufacture. So far as the practical construction goes, however, and without reference to the choice of form, the operations are somewhat as follow :—Whether the boiler be of copper or of iron (copper being the most durable, but iron the most frequently used, probably on account of its greater cheapness), the sheets are chosen of such thickness as is deemed necessary to give the strength required, and is cut to such sizes as will, when bent into the curved shape, form the boiler. Sometimes cast-iron-plate boilers are used; but sheet-metal is much more prevalent. Every sheet or piece being attached to the adjoining one by rivets, the piercing of the holes for these rivets is one of the preliminary operations in boiler-making. The punching-machines employed in engineering differ a little in their construction, but they are always so strongly made, and urged by so great a power, as to pierce through metal with the greatest ease. The punch employed of course varies in size according to the hole to be pierced; but whatever be its size, the sheet of metal is placed beneath it, adjusted accurately, and then pierced through, the small piece of metal falling into a receptacle beneath. The plate or sheet is *shifted* on a few inches at a time, and pierced in the same way, until the whole outer edge of the metal is pierced. In most instances the cutting-engine and the punching-engine are distinct and separate; but there is sometimes a double machine comprising both of these parts: a ponderous upper bar has a punch at one end and a kind of scissor-blade at the other, which, through the vibratory movement of the bar, are brought alternately into action.

All the pierced plates for a boiler require a certain modification of surface to adapt them to the curvature of the boiler. This is effected by hammering on an anvil, a gauge or pattern being applied from time to time to determine the character and amount of curvature. This being effected, the sheets are then fastened together by riveting; and this is in every respect a remarkable process. By the side of the boiler-maker is a small portable forge, expressly intended for heating the rivets. These rivets are short thick pieces of rod-iron with clumsy heads; and before being used they are heated to a red or almost a white heat. The two edges which are to be riveted being lapped one over another, and holes penetrating both of them, a red-hot rivet is put into each hole, and beaten with a powerful hammer until quite hard, by which time the head has become beaten down to a conical form. A man holds a hammer against the other side or end of the rivet, to afford a sufficient resistance to the blows; and he in his turn hammers down the inner end of the rivet. The overlapping edges of the sheet-copper are thus pressed together, not only by the beating which the rivet has received, but also by the contraction which it undergoes by cooling. Every rivet in every joint at every part of the boiler is treated successively in the same way; and thus arises the din and clatter always incident to boiler-making. Funnels for steam-boats, and all large vessels made of sheet-iron or copper, are put together much in the same manner as boilers.

The steam-engine operations connected with casting are very similar in their routine to other kinds of casting. The bed-plates, which go entirely under the engine of a steam-boat, the cylinders, the pistons, the beams, and various other parts, are cast in sand in the first instance, and then worked up to a smooth and polished surface. In the case of a cylinder, where both the outer and inner surfaces are to be regular and uniform, a brick core or mould is built up, in the manner of those used in founding church bells; and an outer casing being also formed, the vacancy between the two forms a receptacle for the melted metal which is to constitute the cylinder. All the cylinders for steam-engines, some of which are of such vast dimensions, are made in this manner. The bed-plates for marine engines are among the most ponderous specimens of casting. Some are thirty or forty tons in weight, and cast at one time in one mould. These bed-plates consist not merely of a stout plate to go entirely beneath the engine, but also of the large vessel in which the steam is condensed, both being cast in one piece. The formation of the mould for these large pieces, the melting of thirty tons of iron in one furnace, and the casting of this metal without the intervention of air-bubbles or impurities, are among the most important operations of these establishments.

The forged and cast masses of iron, whether for shafts, wheels, cranks, cylinders, or any other portions of an engine, all require more or less finishing and adjustment when they leave the forge and the casting-pit; and these finishing operations constitute the most extensive part of the arrangements in an engine-factory. The processes are carried on in several floors of a large building, and involve the use of several distinct classes of working apparatus. One of these, for example, is that for boring cylinders. This does not consist, as the name seems to imply, in boring a cavity through a solid piece of metal, but in giving a perfectly circular form and smooth surface to that which has already been formed by casting. The motion of a piston in a cylinder, to be smooth and air-tight, requires that the internal surface of the cylinder should be rigorously true; and as this exactitude cannot be produced by casting, it is attained by subsequent boring. The cylinder is placed horizontally, and the boring-instrument consists of a cutting edge or tool which revolves in contact with the inner surface of the cylinder. Some boring-machines, such as that represented in the annexed cut, are employed for furnishing smaller circular apertures, and do not differ much in appearance from drilling-machines.

The planing-machines employed in such factories are intended to produce the same effect upon a flat surface as the boring-machines upon a cylindrical surface. Supposing a piece of metal to be cast as flat as possible, but not so level and smooth as the object requires, it is placed horizontally, and the planing-machine passed to and fro over it. There is not to this machine a plane-iron fixed into a box, as for woodwork, but a stout, strong, hard piece of steel, having one edge sufficiently



Boring-machine.

keen to cut away the surface over which it passes, and on which it strongly presses. The beauty of these machines consists in the nice adjustment by which the motion of the cutting edge is kept in one uniform horizontal plane, so as to impart perfect flatness and smoothness to the plate beneath.

Lathes are a kind of working apparatus very extensively used in such establishments. All shafts which have been forged, and all smaller pieces of metal which have been forged or cast, and whose contour is circular, are submitted to the action of the lathe as a means of obtaining perfect circularity of form. The cutting tools are formed of very hard steel, and are applied to the surface of the metal very much in the same way as a wood-turner uses his chisels and gouges. Large wheels, in order to undergo the process of turning after casting, frequently require that a hole should be left in the floor of the shop to admit part of the diameter, as they would else be almost unmanageable.

Screw-cutting machines form another important class of working apparatus, since the screws for a steam-engine, as for any other delicate piece of mechanism, require much accuracy of adjustment. These machines somewhat resemble lathes, in so far as there is a cutting edge applied to a revolving bar of metal; but the distinguishing feature is this, that while the bar which forms the shaft of the screw rotates, the tool which cuts the thread of the screw travels onward from end to end, and the relative velocities of these two movements determine the obliquity of the thread or worm.

Other tools and machines in great variety are required. Piercing-engines, for making holes through sheets and thin plates—drilling-machines, for similarly piercing thicker plates—anvils, files, and a host of others, help to fill up the measure of an engineer's working apparatus. A steam-engine is not "one and undivided;" it is a thing of many parts, each of which requires accurate shaping, smoothing, and adjusting, before it is brought into connection with the rest. But though the pieces thus prepared are exceedingly numerous, the arrangements incident to their preparation have been pretty nearly comprised in those already glanced at—the making of patterns, gauges, and moulds; the casting-pit and its appendages; the forge and its swarthy attendants; the piercing and drilling machines; the cutting-machines; the apparatus and arrangements for riveting; the boring-machines; the lathes and screw-cutting machines; the planing-machines; the hammer, the file, the anvil—these are the agencies, directed by manual dexterity or muscular strength, or both, by which the mighty steam-engine is built up, and its various parts made to combine one with another.

While speaking of the Steam-engine in connection with Ships, it may not be amiss to add a few words concerning the same mighty agent in connection with Railways.

When Mr. George Stephenson was examined before the Committee of the House of Commons, on the Liverpool and Manchester Railway Bill, in 1825, his evidence was such as would excite as much surprise now as it did then; but from a very different reason: his examiners then marvelled at his boldness of prediction; while we at the present day should be much more disposed to wonder at his timidity. He was asked whether the locomotive could travel safely at the rate of five or six miles per hour; and in answer he stated, that he thought even double that rate might be attained. He also stated that he proposed to travel at the rate of eight miles per hour with a burden of twenty tons, and four miles an hour with forty tons:—statements which were laughed at by some parties, and positively disbelieved by others.

What a change has the intervening period of nineteen years effected! How cruelly do third-class passengers now think themselves used if they are whirled *along* at *only* fifteen or twenty miles an hour; and how many "Letters to the Editor" of some one or other of the Journals are there, urging that nothing but a competing line will cure the barbarous slowness of Railway Directors! Those railway trains which used to effect twenty miles within the hour now accomplish twenty-five or thirty; the fifty miles between London and Brighton are now accomplished by some of the trains in an hour and a half; the express trains on the Birmingham line will cover forty miles in the hour; and on the Great Western, still more! And yet with all this, the atmospheric principle of traction is put forth as a formidable antagonist, on the ground (among others) that it will be *quicker* than the locomotive system! The truth is, we are travelling so quickly that we have not time to look behind us to see how great is the path of improvement over which we have passed in the last twenty years.

A locomotive factory, such as that of Messrs. Stephenson at Newcastle, is like all other engineering factories in its general features, having open yards surrounded by buildings, and having in those buildings numerous workshops devoted to the several departments of the manufacture. The parts of a locomotive engine are so numerous, and so different in their form and materials; the introduction of new improvements in every part is so rapid; and the mutual adjustment and fitness of one part to another so necessary, that an engine-factory comprises within itself many different factories or branches of manufacture, all bearing on one point. There are, however, certain broad distinctions which serve to indicate the general character of the operations. First, there is the rough material, iron, steel, copper, or brass, in the form of sheets, bars, and rods; and then implements and processes whereby these are wrought up into usable form, such as those connected with rolling, drawing, casting, boring, turning, planing, drilling, cutting, filing, polishing, and other mechanical operations. However varied may be the appearance of the engines produced at such factories, yet it is by modifications of the processes here enumerated that they are all produced, the skill of the workmen adapting the practical details to the purpose to which the engine is to be applied.

It is impossible to look at the locomotives when in progress—some nearly in a finished state, others in various stages of preparation, and all collectively employing the services of several hundred workmen—without thinking of the steady but incessant steps by which the present state of excellence has been attained in this department of manufacture. It may be interesting to glance rapidly at a few features in this movement, and to see what a locomotive at the present day really is.

About forty years ago, Mr. Trevethick, a mining engineer, constructed the first locomotive engine, and applied it successfully to the traction of coal and ore at Merthyr Tydvil in Wales. The idea was to apply it to common roads; but this was given up, and its use was confined to the tramways at the iron and coal works. In the very first trial it drew several carriages, containing ten tons of iron, the distance being nine miles, and the rate of travelling five miles an hour. When it became proposed to extend this system to other railways, a curious imaginary difficulty started: an objection was raised in theory, which has not been found to be operative in practice. It was supposed that the amount of adhesion between the wheels and the rail would be so small, that the wheels would slip along the rail instead of moving only by revolving on the axis. A cure for the disease was then sought for, before the disease itself had been proved to exist. Messrs. Trevethick and Vivian proposed to make the external rims of the wheels rough and uneven, either by surrounding them with projecting heads of nails or bolts, or by cutting transverse grooves in them, or by some other analogous contrivance. In 1811 a second locomotive was made by Mr. Blenkinsopp, of Middleton Colliery near Leeds, on a very curious plan; the rails themselves, instead of being smooth bars, presented a line of projecting teeth like those of a cog-wheel; and the wheels were furnished with corresponding teeth, which worked between those of the rail; thus having a rather complicated means of avoiding the so much dreaded slipping. In the following year Mr. Chapman contrived a locomotive in which a chain, passing along the middle of the railway, coiled once round a grooved wheel beneath the engine, as a means of preventing the wheels from slipping round instead of progressing. The next following year (1813) witnessed the production of a most singular contrivance; in which a pair of mechanical feet and legs were made to *walk* along in such a manner as to propel the carriage, and prevent the wheels from slipping round; the arrangement was highly ingenious, but superfluous for the object in view.

Whether engineers had not entertained the idea, or did not possess the means, of determining the point, certain it is that it was not till about 1814 that experiments were made to prove that, if the road be pretty level and the rails clean, there is sufficient adhesion between the wheels and the rails to enable the former to progress without slipping. This settled the matter, and a great deal of complicated arrangement was thus effectually got rid of. The mode of connecting the moving power with the wheels, and the position which the cylinder or cylinders occupied in the engine, were next the subject of attention, and numerous modifications of arrangement were successively introduced.

The next and greatest means of improvement was the opening of the Liverpool and Manchester Railway, perhaps the greatest event which the world has ever yet seen in relation to land travelling. The particulars of this undertaking are pretty generally known; and a few words on the matter, therefore, will suffice here. When the directors, after much consideration and many preliminary inquiries, decided to use locomotives, instead of either fixed engines or horse-power, they offered a reward to the owners of the best engine which should enter the lists in a public trial. Accordingly, in 1829, three engines, the Rocket, the Novelty, and the Sanspareil, started for the prize; the conditions being, that the engine should pass over a portion of the line of railway a mile and a half in length, ten times in each direction, making thirty miles in all; with certain restrictions as to weight, fuel, speed, &c. The Sanspareil and the Novelty both met with accidents in the course of the trial, which put them "hors de combat;" and the prize was awarded to Messrs. Stephenson, as the engineers of the Rocket. This engine, at the quickest rate, went at twenty-seven miles an hour, and at the slowest about eleven.

This Rocket, excellent as was its construction relatively to those which preceded it, was a very different engine from those of our own day. Instead of having the cylinders horizontal, it had them inclining obliquely downward from front to back. Instead of having them enclosed within a metallic case or receptacle, they were placed outside the engine, exposed to the cold of the atmosphere. Instead of six wheels, it had four. But it resembled in principle those of modern times in having a tubular boiler, by which a larger surface of water is exposed to the fire than under the old arrangement, and thereby a more rapid generation of steam produced. Since the day when the Liverpool and Manchester Railway opened, and when the locomotive engine showed its wondrous power by travelling at the rate of more than thirty miles an hour (while conveying the wounded body of Mr. Huskisson back to Manchester), there has probably not been a single important part of the engine but what has been subjected to improvements in some form or other. Without attempting the almost endless task of describing the minute details of structure, we may briefly explain how one of these moving masses derives its almost arrow-like speed.

There are two main objects to be attained :—First, to generate the steam which is to do the work; and next, to apply the steam thus generated to the revolution of the wheels; and the parts of the engine are thus conveniently divided into two groups. In the first place, there are the fire and boiler. The fire-place or fire-box is a double receptacle placed at the lower part of the hinder end of the engine; it consists in fact of one box within another, a vacant space of three or four inches between the two being filled with water. The outer fire-box is made of wrought-iron plates, and the inner one generally of copper, but sometimes of iron. The bottom of both boxes is formed of a grate of bars, through which the ashes fall either to the ground or into an ashpit placed below them.

The boiler, which contains the water to be heated by the fire in the fire-box, is a cylinder seven or eight feet long by three or four in diameter, made of very strong wrought-iron plates, and covered on the outside by a casing of wood intended to prevent the heat from radiating too rapidly into the open air. The hinder end of the boiler fits to the front side of the outer fire-box, so as to form a communication between the water in the boiler and that between the two fire-boxes.

The mode in which the gases and heated air (for there is no smoke from the coke fuel), after having heated the water, escape to the funnel or chimney, is one of the most curious features in a modern locomotive, and one to which it owes no small portion of its efficacy. The water in the boiler is not *over* the fire, but in *front* of it, and therefore might seem at first thought to be peculiarly ill fitted to receive the heating power from the fire; but this is brought about by the same agency which conveys the gaseous products of combustion to the funnel in front of the engine. There are upwards of a hundred brass tubes extending from end to end of the boiler, having connection with the inner fire-box at one end, and with the chimney or a receptacle called the smoke-box at the other. These tubes are about an inch and a half in diameter, and are made of rolled brass, the distance between them as they lie being less than an inch.

Let us see, then, how these tubes assist the object in view. Through an oval hole in the fire-box, behind, the fire is lighted; and through a convenient inlet the boiler is filled or nearly filled with water. As the fire-box becomes filled with flame, gas, and heated air, these products find a passage through the hundred or hundred and twenty horizontal tubes, and escape into the smoke-box in front. But as the boiler is filled with water, the exteriors of all these tubes are in contact with the water, and give out heat with so much rapidity as to raise the water to the boiling temperature in an exceedingly short space of time. This is the grand object, to attain which the engineer will willingly incur the extra cost entailed by these tubes. The first locomotives had merely a large flue passing from the fire-place to the chimney; but to have a sufficiently large heating surface under this arrangement would require such large and weighty apparatus that it would be inconsistent with the high velocity at which the engines are intended to more. Accordingly Mr. Stephenson, in planning the Rocket engine, used twenty-four tubes of three inches diameter, instead of a large flue. Under the old form a speed of eight miles an hour was the utmost that could be attained; but this tubular boiler gave such widely different results, that they have been since used almost if not quite universally. By degrees the diameter of the tubes was lessened and their number increased, until at length as many as a hundred and twenty have been adopted. They were at first made of copper, but as these became worn away in three or four months when in regular use, they have been superseded by brass tubes, which last about two years.

Every tube is said to be worth about a guinea, so that the re-tubing of an engine becomes an expensive affair.

The heated air passes into a wrought-iron smoke-box in front of the engine, and from thence up the chimney. In order to drive it violently up the chimney, and thus produce a powerful "draught" in the fire, the waste steam is allowed to rush up the chimney with it, and carry it quickly up.

We have now to see what results from the heated water in the boiler. The steam from the water ascends to the top of a kind of hollow dome, about two feet high above the boiler, and in so doing parts with some of the water which by agitation and shaking had become mixed with it; it then descends a pipe within the dome, and passes along a large steam-pipe to the front of the engine; here it divides into two parts, and descends to supply steam to the two cylinders placed at the front extremity of the lower part of the engine. Each of these cylinders is a cast-iron vessel about a foot in diameter, placed horizontally, and having a solid piston, or plunger, working from end to end within it. Numerous minor pieces of apparatus of great complexity and delicacy are placed near these cylinders, to regulate the entrance of steam into them, and its exit when the required office is performed. The steam drives the piston to and fro, and the piston, through the medium of a rod, turns one of the large wheels by which the whole machine is impelled. Supposing the piston to be at any moment near the front end of the cylinder, steam is admitted in front of it into the cylinder, through an appropriate opening; and its elastic force drives the piston rapidly to the hinder end of the cylinder; the steam then escapes, and another body of steam, entering behind the piston, drives it forward again; this in its turn escapes, and thus a series of alternate movements arise. When we hear the puffs, or apparently laboured breathings of the engine, these are the successive escapings of the steam from the cylinders into the chimney, and from thence into the open air. A cylinder-full of steam is sent forth at each puff, and the driving-wheel is sent round half a revolution. There are two cylinders, one on each side, and it is so arranged that they send out their puffs of steam alternately; every puff, therefore, heard while the engine is moving onwards, is equivalent to one quarter of a revolution of the driving-wheels; and the rapidity of the puffs, taken in conjunction with the diameter of wheels, affords the means of estimating roughly the speed of the engine.

These are the broad principles of the locomotive. The mode of supplying coke and water from the tender behind; the arrangements for governing the heat of the fire; the admission of steam to the cylinder, and the exit of superfluous steam and condensed steam; the safety-valve; the shrill whistle, produced by allowing a current of steam to strike upon a thin metallic edge; the gauges to indicate the state of the water and of the steam in the boiler—all display the highest ingenuity, and are well worthy of the attention of those who like to dive a little beneath the surface of such matters. The factories where such machines are made are necessarily the theatres of some of the highest developments of mechanical art, and are an index to the progress of the age in this direction.

THE END.

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